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CLOUD TOP SCANNING RADIOMETER (CTS)

FINAL REPORT

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Prepared By
HONEYWELL
ELECTRO-OPTICS CENTER
2 FORBES ROAD
LEXINGTON, MASSACHUSETTS 02173

Prepared For
GODDARD SPACE FLIGHT CENTER
GREENBELT, MARYLAND 20771

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HONEYWELL
Electro-Optics Center
2 Forbes Raod
Lexington, Massachusetts 02173

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SECTION I
INTRODUCTION AND SUMMARY

In accordance with the specifications of contract number NAS5-22459, awarded by the Goddard Space Flight Center (GSFC), the Honeywell Electro-Optics Center has designed, built and tested a scanning radiometer, the Cloud Top Scanner (CTS), to be used for measuring cloud radiances in each of three spectral regions. This final report describes the instrument design and presents system test and calibration data.

The CTS has been designed to be a rugged and versatile scientific instrument which will be readily adaptable to minor changes of mission or experiment.

Significant features incorporated in the instrument design are:

- Flexibility and growth potential through use of easily replaceable modular detectors and filters.
- Full aperture, multilevel inflight calibration.
- Inherent channel registration through employment of a single shared field stop.
- Radiometric sensitivity margin in a compact optical design through use of Honeywell developed (Hg,Cd)Te detectors and preamplifiers.

SECTION 2
REQUIREMENTS

Scientific objectives to precisely image and accurately measure cloud radiances in three spectral regions dictated performance requirements of the Cloud Top Scanner.

2.1 SCIENTIFIC REQUIREMENTS

The scientific purposes of the Cloud Top Scanner (CTS) require that infrared and visible energy be collected from the same instantaneous field of view and that a wide swath width be employed so that efficient ground or cloud area coverage is obtained. In addition, clouds are to be imaged in three dimensions so that the relationship between cloud motions and winds can be studied as well as measuring cumulonimbus cloud top height and localized cumulonimbus upper surface temperature changes so that their relationship to severe storms can be studied. For these purposes, it is necessary to make radiometric measurements in a water vapor absorption band so that the clouds will appear opaque against the earth surface background. The CTS Channel 2 band of 6.6 to 6.9 μm is well suited for this purpose because it is both a strong absorption band and because it is in an unambiguous region of the spectrum. See Figure 2-1.

The presence of a visible spectral band allows correction of radiometric data for solar effects and allows the further study of the Shenk-Curran method of determining cirrus cloud top height. Since high thin clouds contain ice crystal platelets which can become aligned by electrostatic and other forces, these clouds can deviate significantly from blackbody behavior. The measurement of cloud reflectance in the 0.55 to 0.75 μm band (CTS Channel 1) allows a correction to be made to the infrared radiance measurements and the blackbody temperature calculation is much improved.

Channel 3 operates in the 10.5 μm to 12.5 μm region. This is a region of high atmospheric transmittance and is useful, therefore, in measuring earth or sea surface radiances.

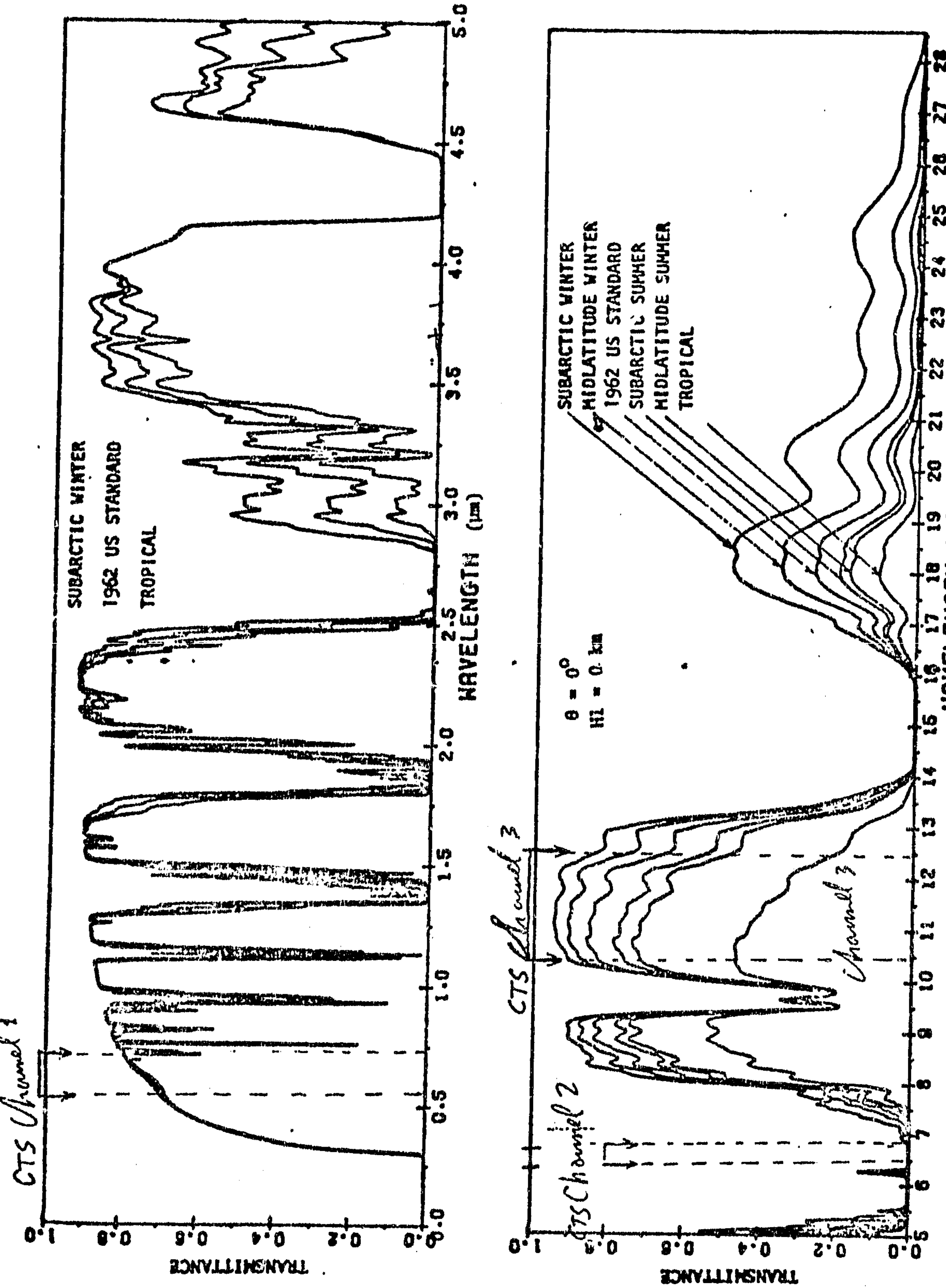

Figure 2-1 Atmospheric Transmittance for a Vertical Path to Space from Sea Level for Six Model Atmospheres

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Scientific objectives require precise radiometry so that in the design of the CTS instrument, emphasis was placed on calibration accuracy and system linearity.

2.2 SYSTEM PERFORMANCE REQUIREMENTS

Performance requirements are derived from the scientific objectives. Instrument design was configured to insure meeting all scientific objectives and all requirements given in the work statement. Table 2-1 is a summary of system specifications.

Table 2-1 SYSTEM PERFORMANCE REQUIREMENTS

SPECIFICATION	CHANNEL NUMBER		
	1	2	3
• RADIOMETRIC RESPONSE			
— SENSITIVITY	0.32 W/m^2-sr (goal)	1 K^0 @ 185^0K	0.3 K^0 @ 185^0K
— MAXIMUM SIGNAL	96.1 W/m^2-sr	285^0K	325^0K
— LINEARITY (DEVIATION FROM LEAST SQUARES)	$\pm$ 2%	----	----
— POLARIZATION SENSITIVITY	≤ 0.05	----	----
• SPECTRAL RESPONSE	$0.55 \leq \lambda(\mu m) \leq 0.75$	$6.6 \leq \lambda(\mu m) \leq 6.9$	$10.5 \leq \lambda(\mu m) \leq 12.5$
• SPATIAL RESPONSE			
— IFOV	6.2 mr	6.2 mr	6.2 mr
— FOV	$\pm 60^0$	$\pm 60^0$	$\pm 60^0$
— MTF @ 1 IFOV	≥ 0.35	≥ 0.35	≥ 0.35
— IFOV REGISTRATION	0.6	0.6	0.6
• CALIBRATION			
— ACCURACY	$\pm$ 3% of full scale	± 1.9 K^0 @ 185^0K	± 0.9 K^0 @ 185^0K
— REPEATABILITY	$\pm$ 1% of full scale	± 1 K^0 @ 185 ^0K	± 1 K^0 @ 185 ^0K

SECTION 3
INSTRUMENT DESIGN

3.1 SYSTEM DESCRIPTION

The Cloud Top Scanning Radiometer (CTS) is a three-channel absolute radiometer designed to scan clouds while looking downwards from an RB57F aircraft flying at 60,000 feet altitude. Two infrared channels and one visible channel have 6.2 milliradian IFOV and are scanned laterally to the direction of aircraft motion in a single-line scan having 120-degree swath width. This scanning pattern coupled with the aircraft motion provides an effective raster scan of clouds against the earth background, giving information on cloud temperature distribution and structure. The two infrared channels of the CTS system have been chosen in the 6.6-6.9 m water-vapor absorption band (Channel 2) and in the atmospheric window region at 10.5-12.5 μm (Channel 3). In the former the clouds will appear as opaque against the earth background whereas in the latter, radiometric imaging of the earth's surface is possible, even for regions of high thin cirrus clouds. The visible channel (Channel 1, 0.55-0.75 μm) records reflected and scattered sunlight from the cloud/earth scene.

A composite system drawing is shown in Figure 3-1. Figure 3-2 is a system block diagram.

A flat scanning mirror set at 45 degrees scans a 120-degree arc below the instrument and fills the 8-inch aperture of a Cassegrain telescope. A common field stop defines the common instantaneous field-of-view of all three spectral bands and effectively isolates the rear optics from stray radiation. A rotating chopper wheel modulates the radiation after it leaves the field stop to permit ac coupling of the signal electronics and eliminate detector 1/f noise.

A gold coated beamsplitter separated the IR channels from the visual channel by transmitting Channel 1 signals (0.55 μm to 0.75 μm) while reflecting the longer wavelengths of Channels 2 (6.6 μm to 6.9 μm) and Channel 3 (10.5 μm to 12.5 μm).

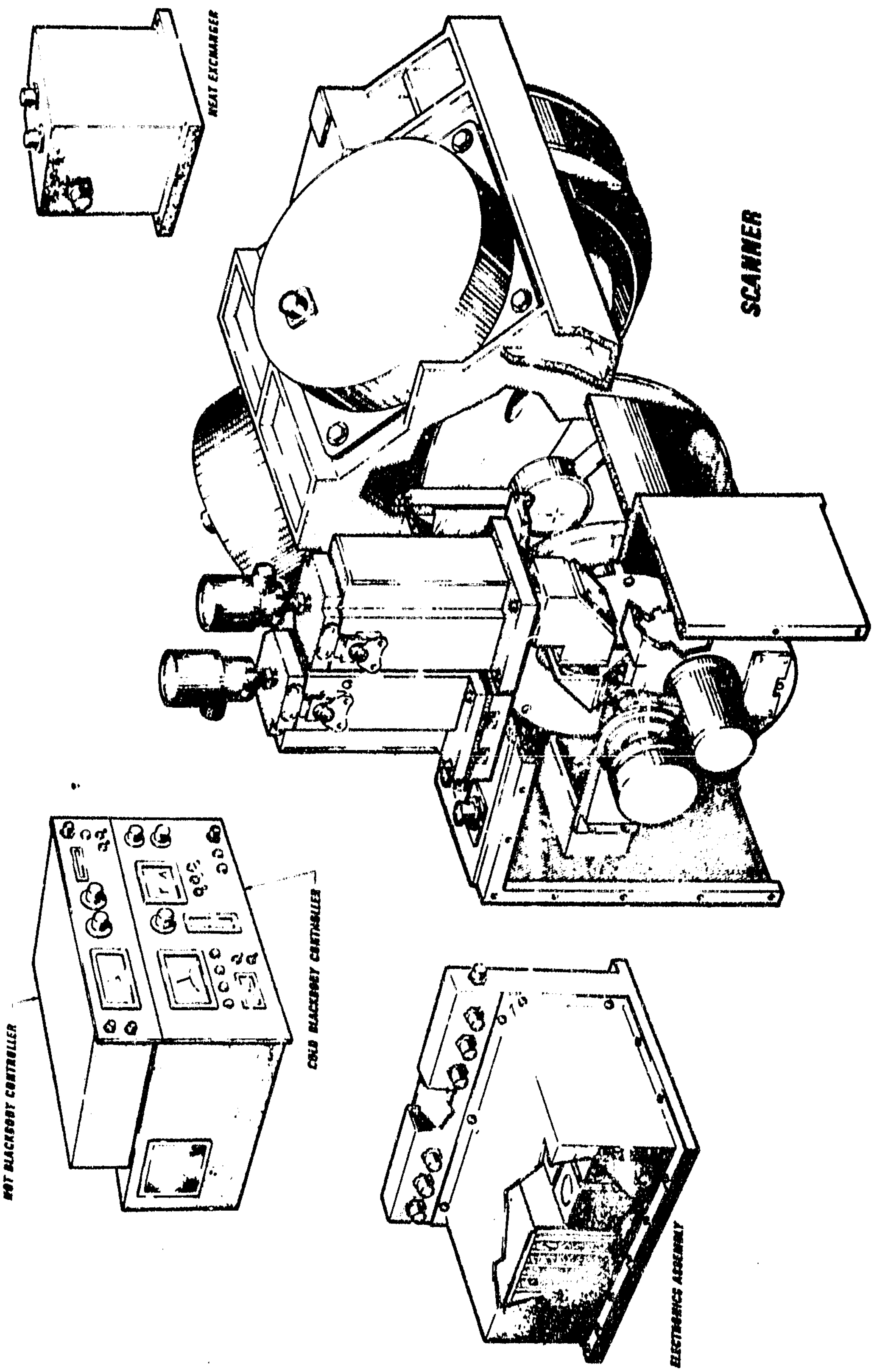

Figure 3-1 System Composite

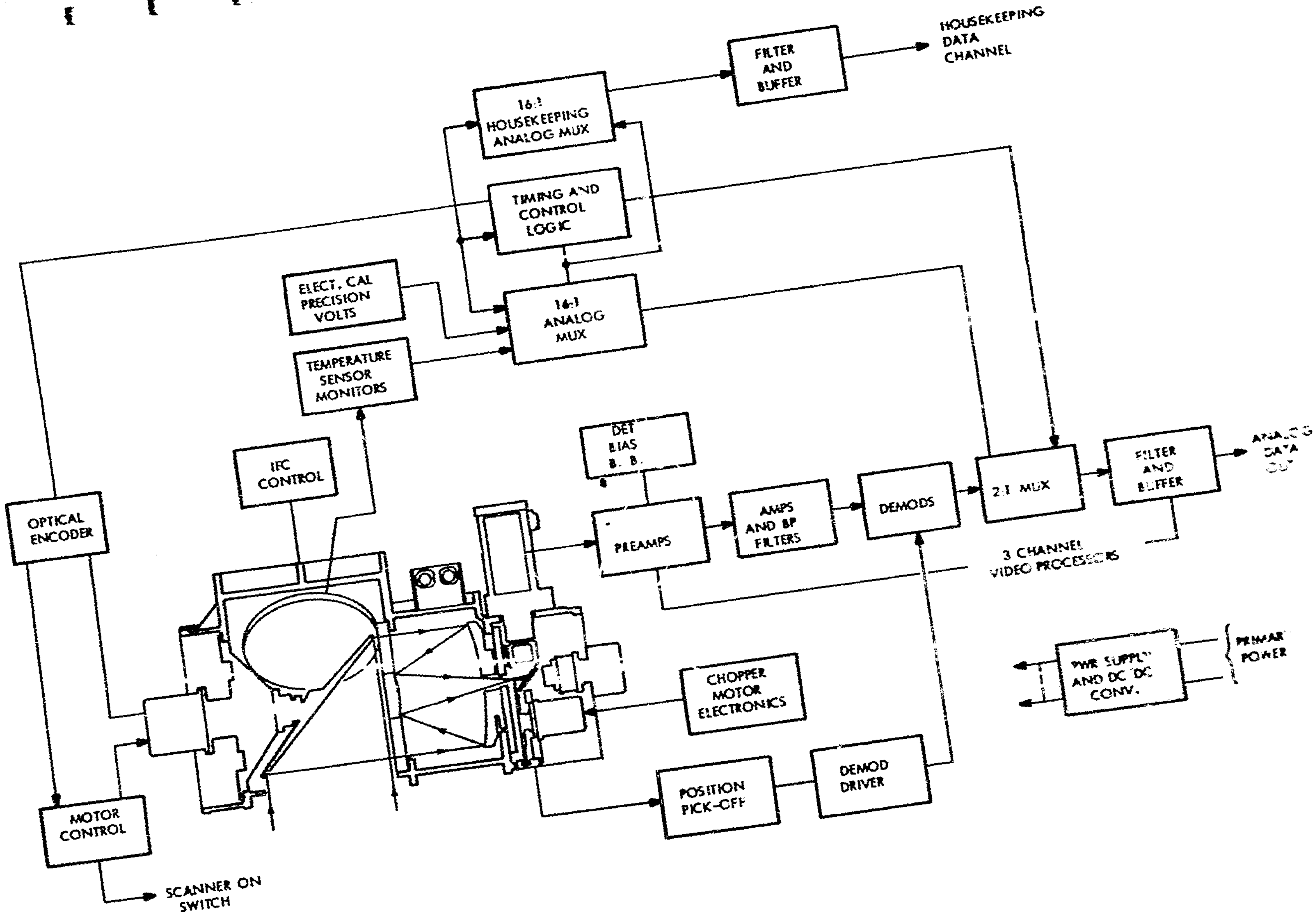

Figure 3-2 CTS System Block Diagram

The image of the common field stop is relayed to each detector by collimating and recollecting optics in each channel. Spectral filters are located in each collimated relay beam and can be easily changed when required by the experiments.

The (Hg,Cd)Te infrared detectors are mounted in glass liquid nitrogen dewars with over 8 hours hold time. Each is potted inside a metal housing to provide a rugged and easily replaceable unit. Metal mirrors are used throughout the design for ease of mounting and because of their ability to maintain optical quality over a considerable range of temperature. The optics are supported by a rigid aluminum casting, which also facilitate assembly.

In order to achieve the full benefits of an accurate primary calibration, the CTS has been designed for high inflight stability. Stability is achieved by clamping the chopper radiance signs to a known voltage level. The chopper is effectively used as a transfer standard between the unknown scene radiance and the in-flight calibration sources (IFC sources). Inflight calibration checks are performed in channels 2 and 3 during the backside portion of each scan. A hot blackbody and cold blackbody source are scanned in succession by the rotating scan mirror.

The instrument electronics, comprised of linear and digital circuitry, performs the required signal conditioning, timing, and control functions.

Table 3-1 is a summary of system weight and power requirements.

3.1.1 Radiometric Analysis

Radiometric sensitivity of the CTS is defined by the following equations:

Visible Channel

$$NE\Delta N = \frac{(NEP/Hz^{1/2})\ \Delta f_n^{1/2}\ \alpha_{ch}\ \alpha_e}{A_o\ \omega^2\ \tau_o} \qquad (1)$$

Table 3-1 WEIGHT, SIZE AND POWER SUPPLY

PARAMETER	TOTAL	SCANNER	ELECTRONIC BOX	HOT BB CONTROLLER	COLD BB CONTROLLER	HEAT EXCHANGER
DIMENSIONS W x L x H	11 ft^3	18 1/2" x 30" x 21"	12" x 18" x 13"	19" x 9" x 3 1/2"	7" x 14" x 19"	8" x 8" x 8"
WEIGHT	191 POUNDS	110 POUNDS	40 POUNDS	6 POUNDS	15 POUNDS	20 POUNDS
POWER GROUND OPERATION	200 W.D.C. 300 W.A.C.	40 W.D.C.	160 W.D.C.	200 W.A.C.	100 W.A.C.	0
POWER FLIGHT	120 W.D.C. 800 W.A.C.	20 W.D.C.	100 W.D.C.	200 W.A.C.	500 W.A.C.	100 W.A.C.
POWER DESCENT	750 W.A.C.	550 W.A.C.	0	100 W.A.C.	100 W.A.C.	0

Infrared Channels

$$\mathrm{NE\Delta T} = \frac{A_d^{1/2} \quad \Delta_{fn}^{1/2} \quad \alpha_{ch} \quad \alpha_e}{\left(\frac{\partial N}{\partial T}\right)_{\Delta\lambda} \quad \omega^2 \; A_o \; D^* \; \tau_o} \tag{2}$$

Table 3–2 gives the design parameters for the pertinent terms in equations 1 and 2, in order to satisfy a 0.32 watt/m^2-s NEΔN (Channel 1) and an NEΔT at 185 K of 1 K and 0.3 K, respectively, for Channels 2 and 3. An eight-inch aperture (292 cm^2) provides sufficient design margin.

In the sensitivity calculations, several considerations are worth noting. First, the noise bandwidth has been calculated to be 1012 Hz which assumes a four-pole Butterworth noise limiting filter which degrades the information bandwidth by a factor of 1.1. Second, the chopper has an rms conversion factor α_{ch} which degrades the signal. For perfect square wave chopping α_{ch} = 1.57, where the chopper opening is many times the beamwidth. In the proposed CTS design, the chopper opening is 1.5 times the beamwidth so that the resulting trapezoidal waveform is close to the triangular wave resulting for a 1:1 size ratio. The degradation factor for this design is α_{ch} = 1.9, as shown in Figure 3–3. Third, the electronic noise in the processing circuits also add noise. The value of α_e = 1.7 is used here in agreement with that suggested by L. Goldberg in his discussion of signal-to-noise in the AVHRR paper, NASA N68-17253.

3.1.2 Detector Requirements

From the equation in Table 3–2, $D^*_{\Delta\lambda}$ requirements are derived for both (Hg,Cd)Te detectors. Specifications for these are given in Table 3–3 . Sensitivity requirements for the silicon detector is given by:

$$\mathrm{NEP'} = 1.8 \times 10^{-11} \ \mathrm{watts/Hz^{1/2}} \tag{3}$$

Table 3-2 SENSITIVITY ANALYSIS

PARAMETER	SYMBOL	CH 1	CH 2	CH 3	UNITS
DETECTOR-AREA	A_d	0.05	0.05	0.05	cm^2
NOISE BANDWIDTH	Δf_n	1012	1012	1012	Hz
CHOPPER CONVERSION FACTOR	α_{CH}	1.9	1.9	1.9	---
ELECTRONIC NOISE FACTOR	α_e	1.7	1.7	1.7	---
INCREMENTAL RADIANCE WITH TEMPERATURE	$\left.\frac{\partial N}{\partial T}\right\rfloor_{185}$	---	1.58×10^{-7}	4.97×10^{-6}	$W/cm^2\text{-}sr\text{-}K^0$
SOLID ANGLE	Ω	3.84×10^{-5}	3.84×10^{-5}	3.84×10^{-5}	sr
ENTRANCE APERTURE	A_0	324.3	324.3	324.3	cm^2
$D^*\Delta\lambda$	$D^*\Delta\lambda$	---	3.5×10^{10}	1.5×10^{10}	$cm\text{-}Hz^{1/2}/W$
OPTICAL EFFICIENCY	τ_0	0.13/0.16	0.41/0.44	0.28/0.39	---
NOISE EQUIVALENT POWER	NEP'	1.8×10^{-11}	---	---	$W/Hz^{1/2}$
SENSITIVITY REQUIRED	NEN (CH 1) NETD (2,3)	0.32 (goal) $W/m^2\text{-}sr$	$1\ K^0$	$0.3\ K^0$	---
PREDICTED SENSITIVITY SPEC/GOAL	NEN (1) NETD (2,3)	0.011/0.009	0.81/0.76	0.09/0.06	---

$$NETD = \frac{A_d^{1/2}\ \Delta f_n^{1/2}\ \alpha_{CH}\ \alpha_e}{\left.\frac{\partial N}{\partial T}\right\rfloor_{185^0 K}\ \Omega A_0\ \Delta\lambda\ \tau_0} \qquad NEN = \frac{(NEP')\ \Delta f_n^{1/2}\ \alpha_{CH}\ \alpha_e}{A_0\ \Omega\ \tau_0}$$

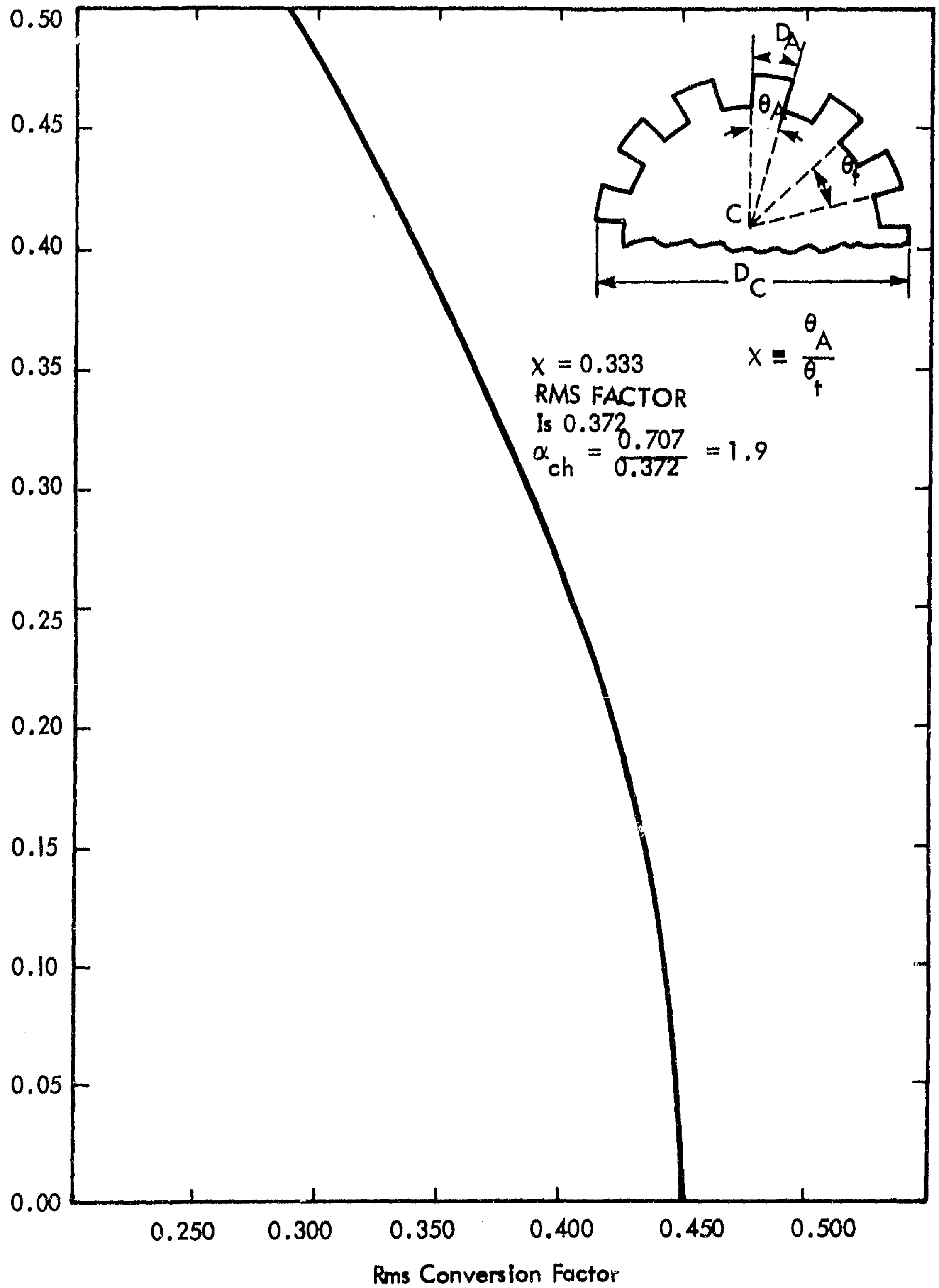

Figure 3-3 Chopper RMS Conversion Factor for Square IFOV for Various Chopper Geometrics

Table 3-3 HCT DETECTOR SPECIFICATION

- PACKAGE: GLASS DEWAR SIMILAR TO DLK-51F
  HOUSING NOT DETERMINED
- DETECTORS: 1 EACH 6.6-6.9 μm AND 10.5-12.5 μm
- REQUIREMENTS:

<u>6.6-6.9-μm CHANNEL</u> (x ~ 0.25)

0.080 x 0.080 ($\pm$ 0.002)
77^{0}K OPERATION 300^{0}K B.G.
60^{0} FOV
D^*_{λ} (6.6-6.9, 4 kHz, 500^{0}K) $\geq 3.5 \times 10^{10}$
R_{λ} (6.6-6.9) $\geq$200 V/W (500 typ)
$20 < R_D < 100$ (55 typ)
1/f KNEE $\leq$ 2 kHz
$V_N \sim 3 \times 10^{-9}$
WINDOW: AR-COATED Ge

<u>10.5-12.5-μm CHANNEL</u> ($x \leq 0.2$)

0.080 x 0.080 (+ 0.002)
77^{0}K OPERATION 300^{0}K B.G.
60^{0} FOV
D^*_{λ} (10.5-12.5, 4 kHz, 500^{0}K) $\geq 1.5 \times 10^{10}$
R_{λ} (10.5-12.5) $\geq$200 V/W (250 typ)
$10 \leq R_D < 100$ (35 typ)
1/f KNEE $\leq$ 2 kHz
$V_N \sim 3.4 \times 10^{-9}$
WINDOW: AR-COATED Ge

Silicon detectors with the above performance are readily available "off-the-shelf".

3.1.3 Spatial Response

Spatial response of a scanning system is accurately described by its modulation transfer function (MTF). The MTF is the instrument's amplitude response to a set of spatial frequencies in object space.

System MTF can be calculated by taking the product of the Fourier transforms of optics blur and detector spatial and temporal response and multiplying the result with the electronics frequency response. The resulting graph is shown for channel I in Figure 3-4.

3.1.4 Calibration

Instrument in-flight-calibration consists of two large area blackbody sources located in object space as shown in Figure 3-5. These sources are large enough to completely fill the field of view for a minimum calibration dwell angle of 7.2 degrees. Calibration occurs once per scan line. Table 3-4 summarizes specifications for the two sources and predicted system accuracy for the two infrared channels. A detailed description of the calibration sources can be found in Appendix A.

Channel I is not calibrated during flight. Stability of this channel is obtained, however, by accurately controlling the silicon detector temperature to minimize responsivity variations.

A rotating emissive chopper blade serves as a reference system during the active scan time and is used to minimize effects of 1/f noise and low frequency system drifts.

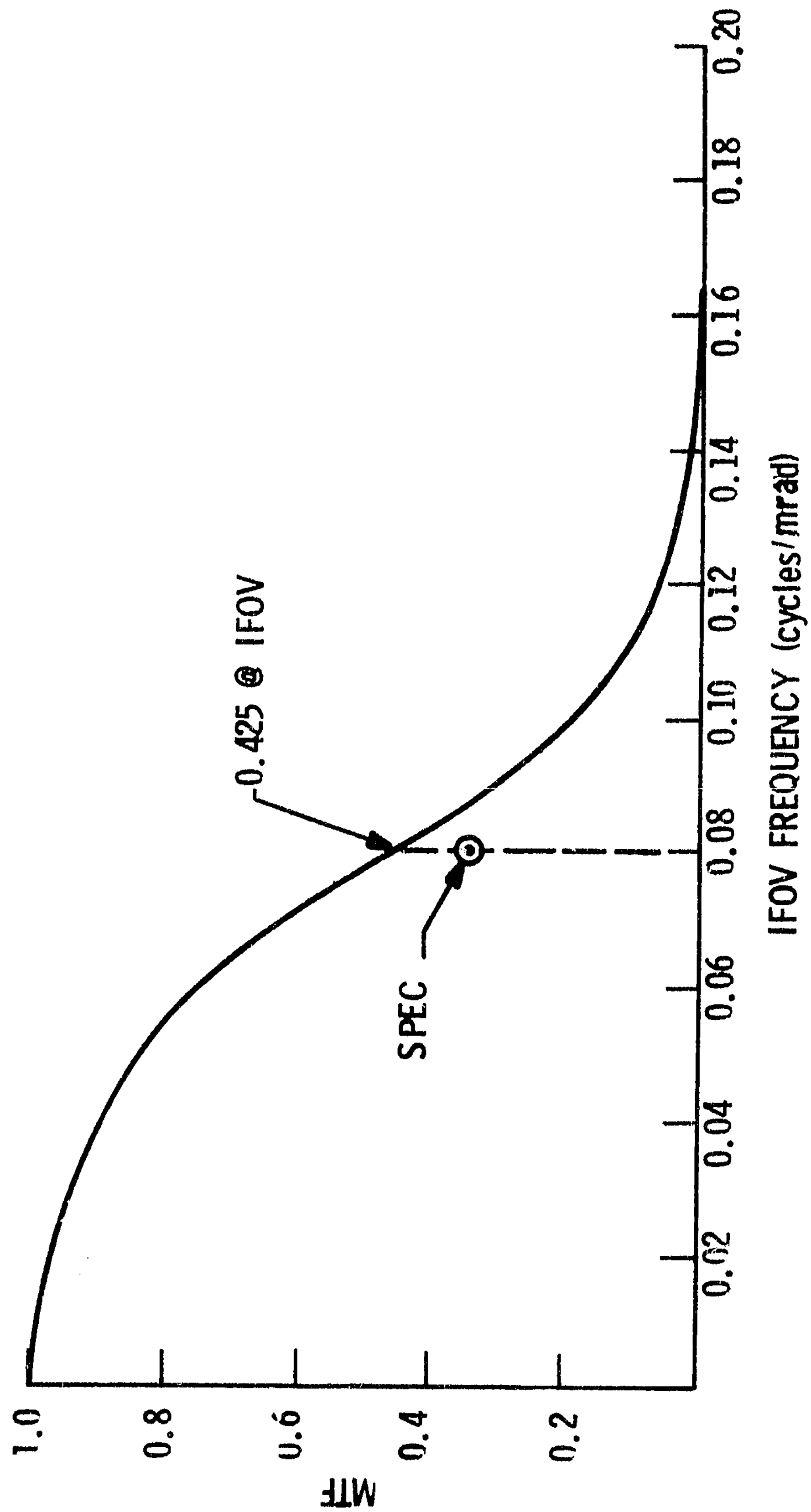

Figure 3-4 CTS System MTF Channel I

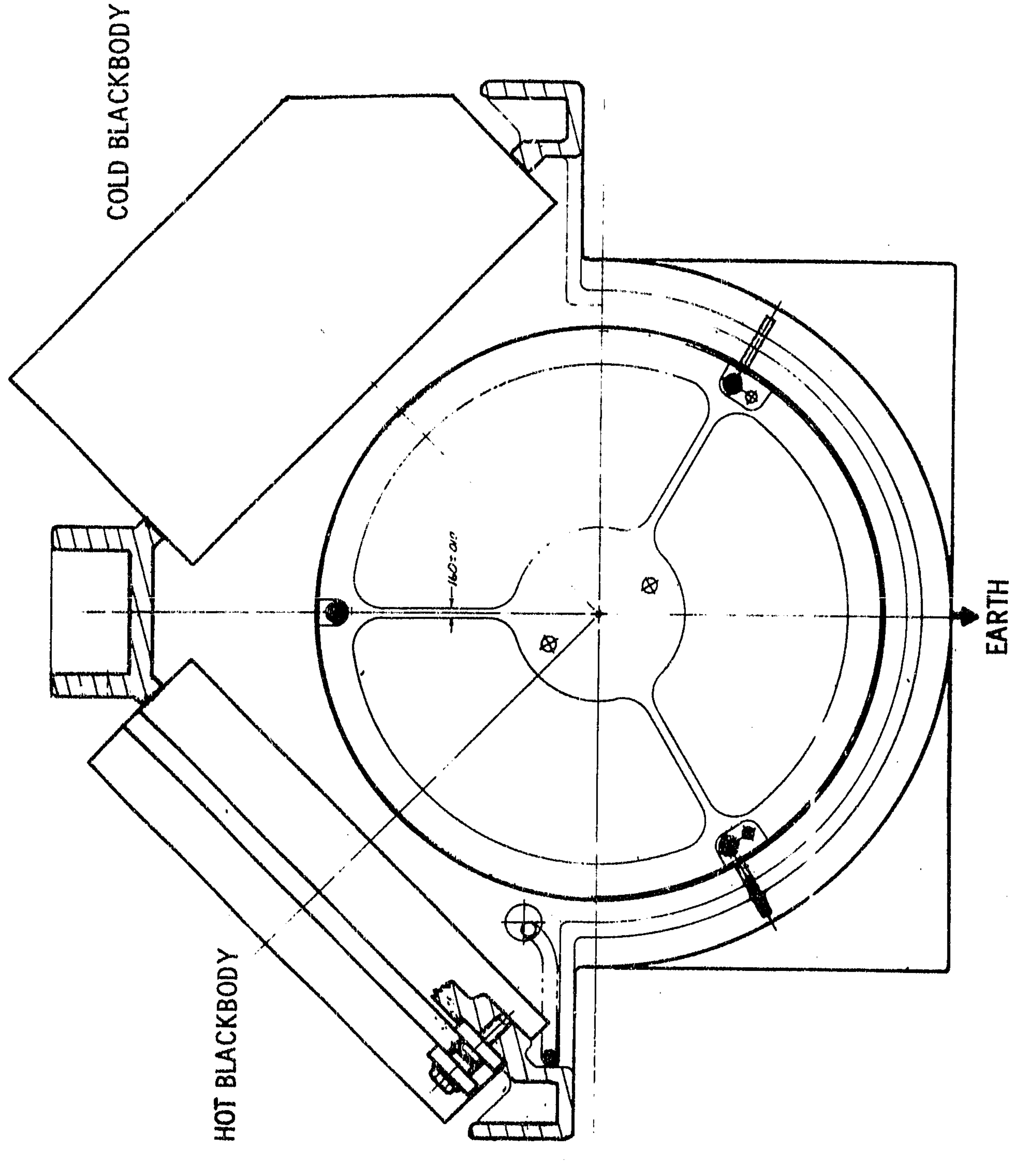

Figure 3-5 Calibration

Table 3-4 CTS IN-FLIGHT CALIBRATION

- CALIBRATION METHOD: TWO LARGE AREA BLACKBODIES IN OBJECT SPACE

- BLACKBODIES DESCRIPTION

HOT BLACKBODY (BB_H) TEMPERATURE	$280\,^0K$
COLD BLACKBODY (BB_C) TEMPERATURE	$20\ K^0$ BELOW AMBIENT
EMISSIVITY	≥ 0.98
BB TEMPERATURE MEASUREMENT ACCURACY	$\pm 0.05\ K^0$
CALIBRATION DWELL ANGLE	7.2^0

- SYSTEM ABSOLUTE ACCURACY

CHANNEL 2	$\pm 1.9\ K^0$ @ $185\,^0K$
CHANNEL 3	$\pm 0.9\ K^0$ @ $185\,^0K$

3.1.4.1 Error Analysis

In determining the optimum calibration and chopper configuration, a detailed error analysis was performed to arrive at comperative performance estimates for various systems. Several methods have been investigated including the use of large area blackbodies, multiple small area blackbodies in object space, and the proposed scheme of small area blackbodies in a focused beam.

A summary of the equations is given in the following section.

3.1.4.1.1 Derivation of Equations

Symbols used in the derivation and their definitions are listed below:

N	=	Radiance (watts/cm^2 - sr)
T	=	Temperature (K)
ε_e	=	Effective emittance of in-flight calibration source
V	=	Signal (volts)
m	=	Calibration curve slope(W/cm^2 - sr/volts)
N_o	=	Calibration curve offset (W/cm^2 - sr)
NEN	=	Noise equivalent radiance
τ	=	Transmittance
ρ	=	Reflectance
H	=	High Calibration Source
L	=	Low Calibration Source
HNG	=	Housing
R	=	Reference Source
RLOPT	=	Reflective Optics (Telescope)
P	=	Primary Calibration Source (Ground Calibration)
IFC	=	In Flight Calibration
δ	=	Error or unmonitored change in quantity
t	=	Target or object to be measured
A	=	Ambient of primary calibration source
$\frac{\partial N}{\partial T}$	=	Incremental radiance per K at temperature T (W/cm^2 - sr - K)

Figure 3-6 shows the expected Cloud Top Scanner calibration curve for Channel 3 where input signal radiance (measured at the entrance aperture) is plotted as a function of output voltage. Voltage levels for both in-flight calibration (IFC) sources are indicated (V_H, V_L).

The actual slope and intercept of the calibration curve is determined in flight by means of the IFC sources.

Target radiance is given by the following equation:

$$N_t = mV_t + N_o \tag{4}$$

The error in target radiance is then given by:

$$\delta N_t = m\delta V_t + V_t\delta m + \delta N_o + \delta N_{PCAL} \tag{5}$$

where N_{PCAL} is the radiance error in primary instrument calibration. Since all of the error terms in the above equation are nearly independent, the most probable system error is the root sum squared value:

$$\delta N_t = \left\{(m\delta V_t)^2 + (V_t\delta m)^2 + (\delta N_o)^2 + (\delta N_{PCAL})^2\right\}^{1/2} \tag{6}$$

3.1.4.1.2 Slope (m)

Slope of the calibration curve is determined by measuring the radiance signal from the IFC sources and comparing these to readings from the calibration temperature monitors:

$$m = \frac{\varepsilon_e(N_H - N_L)}{V_H - V_L} \tag{7}$$

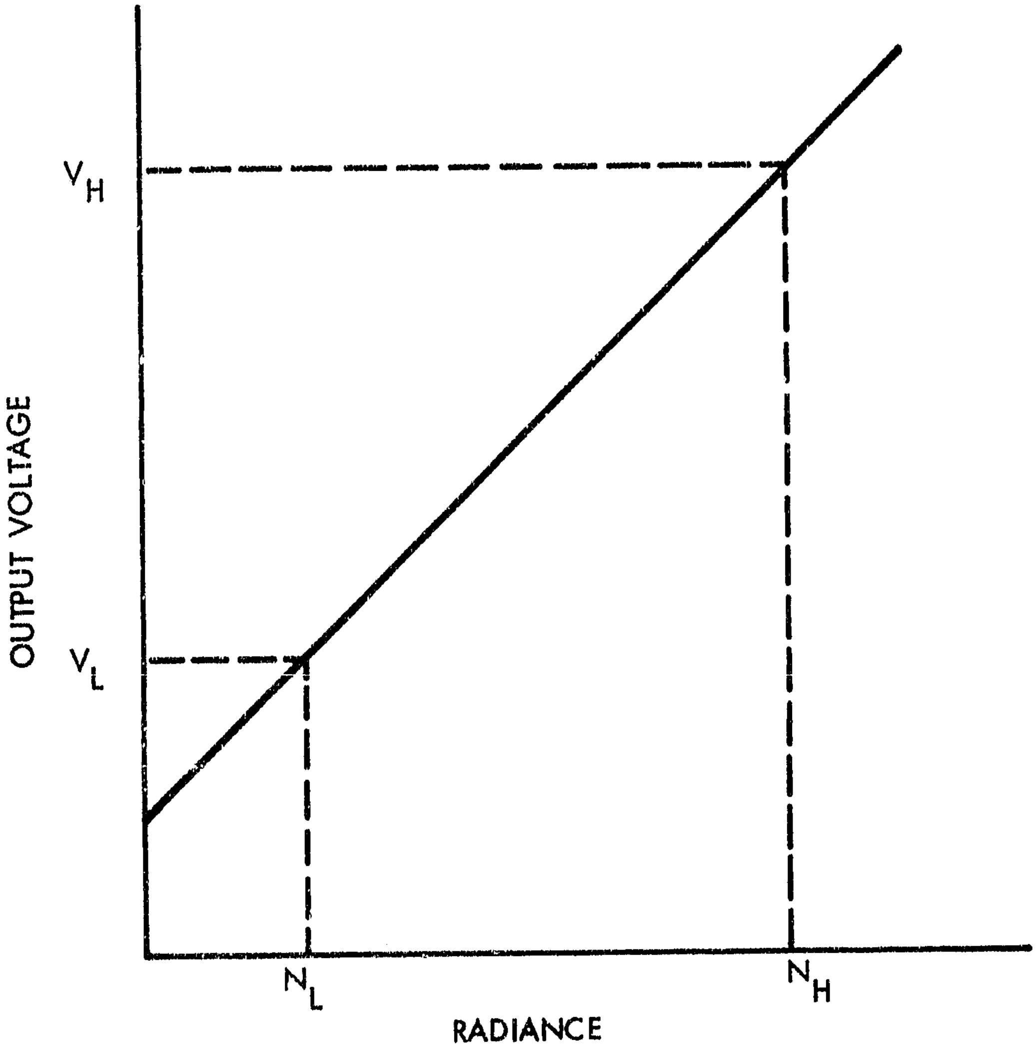

Figure 3- 6 Typical CTS Calibration Curve

where N_H and N_L are the in-band radiance of the high and low calibration sources, respectively calculated from the IFC temperature.

$$V_H = \frac{N_H - N_{185}}{m'}; \qquad V_L = \frac{N_L - N_{185}}{m'} \tag{8}$$

m' = slope of calibration curve obtained during primary ground calibration

$$m' = \frac{N_{325} - N_{185}}{9.8 \text{ volts}} \tag{9}$$

3.1.4.1.3 **Error in Measuring Target Voltage** (dV_t)

$$\delta V_t = \frac{1}{m} \left\{ NEN^2 + \delta N_R{}^2 + (\delta(1 - \tau_{RLOP}) N'_{HNG})^2 \right\}^{1/2} \tag{10}$$

$\delta N_R = \delta T_R \; \partial N/\partial T \rfloor_r$ where δT_R = change in reference temperature between time of in-flight calibration and time of data taking:

$$\delta V_t = \frac{1}{m} \left\{ NEN^2 + [(\delta T_R \; \partial N/\partial T \rfloor_R)^2 + (1 - \tau_{RLOPT}) \; \delta N'_{HNG} - N_{HNG} \; \delta\tau_{RLOPT}]^2 \right\}^{1/2} \tag{11}$$

where $\delta\tau_{RLOPT}$ = change in telescope reflectance between IFC time and data time

$$\delta\tau_{RLOPT} \cong 0 \tag{12}$$

$$\begin{aligned} \delta N'_{HNG} &= \text{change in housing radiance between IFC time and data time} \\ \delta N'_{HNG} &= \delta T'_{HNG} \; \partial N/\partial T \rfloor_{HNG} \\ \delta T'_{HNG} &= \delta T_R \text{ and } \partial N/\partial T \rfloor_{HNG} \cong \partial N/\partial T \rfloor_R \end{aligned} \tag{13}$$

because the housing and chopper reference are at approximately the same temperature.

3.1.4.1.4 <u>Target Voltage</u> (V_t)

$$V_t = \frac{1}{m'} \quad (N_t - N_{185}) \tag{14}$$

at a target temperature $T_t = 185$ K, $N_t = N_{185}$ and $V_t = 0$

3.1.4.1.5 <u>Error in Slope</u> (δm)

$$m = \frac{\varepsilon_e (N_H - N_L)}{V_H - V_L} \tag{15}$$

$$\delta m = \frac{\delta\varepsilon_e (N_H - N_L) + \varepsilon_e \; \delta(N_H - N_L)}{V_H - V_L} - \frac{\varepsilon_e (N_H - N_L)}{(V_H - V_t)^2} \quad \delta(V_H - V_L)$$

$$\frac{N_H - N_L}{V_H - V_L} = m' \approx m$$

$$\delta(N_H - N_L) = \delta T_{IFC} \left(\frac{\partial N}{\partial T} \Big]_H - \frac{\partial N}{\partial T} \Big]_L \right) \tag{16}$$

$$\delta(V_H - V_L) = \sqrt{2} \;\; NEN/mn^{1/2}$$

n = number of dwell times on the IFC sources.

$$\delta m = m \, \delta\varepsilon_e + \left(\frac{\varepsilon_e}{V_H - V_L} \right) \left[\delta T_{IFC} \left(\frac{\partial N}{\partial T} \right) \Big]_H - \frac{\partial N}{\partial T} \Big]_L \; \frac{\sqrt{2} \; NEN}{n^{1/2}} \right] \tag{17}$$

3.1.4.1.6 <u>Error in Offset Radiance</u> (δN_o)

$$\varepsilon_e \; N_H + (1 - \varepsilon_e) N_{HNG} = m V_H - N_o$$

(from graph) (18)

$$\varepsilon_e \; N_L + (1 - \varepsilon_e) \; N_{HNG} = m V_L - N_o$$

where

$$\delta N_{HNG} \quad \delta T_{HNG} \left.\frac{\partial N}{\partial T}\right]_H$$

δT_{HNG} error in determining housing temperature

δT_{IFC} = error in measuring IFC temperature

3.1.4.1.7 Error during Primary Ground Calibration (δN_P)

$$\delta N_P = \epsilon_{eP}\delta T_P \left.\frac{\partial N}{\partial T}\right]_P + N_P\,\delta\epsilon_{eP} + (1 - \epsilon_{eP})\,\delta N_A + N_A\,\delta(1 - \epsilon_{eP}) \tag{23}$$

after rearranging terms and taking the RSS value.

$$N_P = \left\{\left[\delta T_P \;\epsilon_{eP} \left.\frac{\partial N}{\partial T}\right]_P\right]^2 + \left[\delta T_A (1 - \epsilon_{eP}) \left.\frac{\partial N}{\partial T}\right]_A\right]^2 + \left[\delta\epsilon_{eP}(N_P - N_A)\right]^2\right\}^{1/2} \tag{24}$$

3.1.4.1.8 Error In Target Temperature (T_t)

$$\delta T_t = N_t / \left.\frac{\partial N}{\partial T}\right]_t \qquad \text{where } T_t = 185\text{ K} \tag{25}$$

3.2 OPTICAL DESIGN

The overall CTS optical system raytrace is shown in Figure 3-7 and an optical elements list is given in Table 3-5. The wide field of view (FOV) requirement ($\pm 60^\circ$) necessitated the use of an object plane reflective scanner.

An 8-inch aperture Cassegrain telescope has been chosen for the main collecting optics, Its f/1.0 primary mirror (a parabola) and a hyperbolic secondary mirror provide a very compact collecting system, while the f/3 speed at the field stop allows sufficient back focus for the rest of the system to be placed in an optimum location.

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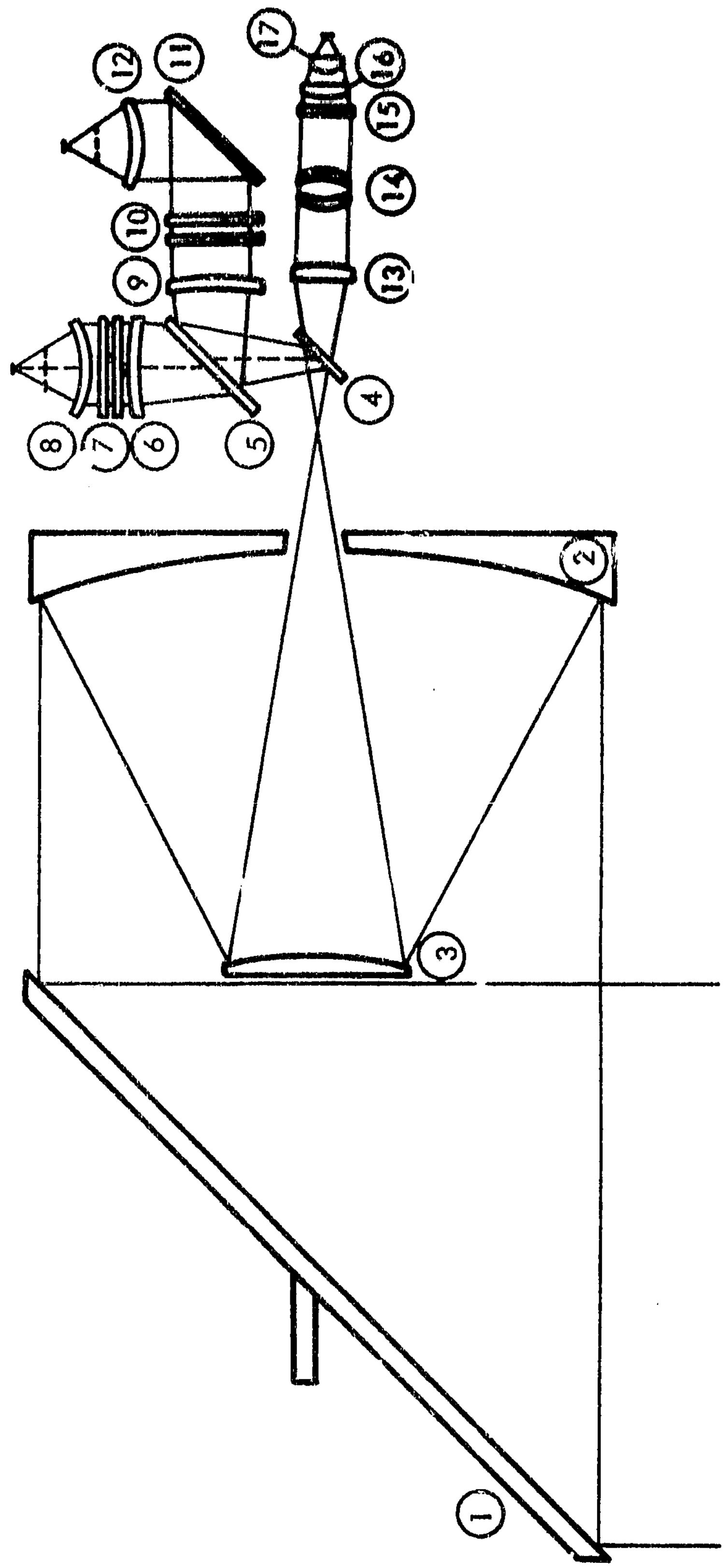


Figure 3-7 Optical Ray Trace

Table 3-5 OPTICAL ELEMENTS LIST

ELEMENT NUMBER	FUNCTION	MATERIAL	TRANSMITTANCE SPEC			TRANSMITTANCE GOAL		
			CH 1	CH 2	CH 3	CH 1	CH 2	CH 3
1	SCANNER	Au COATED Be	0.85	0.97	0.97	0.85	0.97	0.97
2	PRIMARY	Au COATED Al	0.85	0.97	0.97	0.85	0.97	0.97
3	SECONDARY	Au COATED Al	0.85	0.97	0.97	0.85	0.97	0.97
4	BEAMSPLITTER (1)	Au COATED BX-7	0.60	0.90	0.90	0.60	0.90	0.90
5	BEAMSPLITTER (2)	GERMANIUM	----	0.96	0.85	----	0.96	0.85
6	LENS CH 3	GERMANIUM	----	----	0.80	----	----	0.94
7	FILTER CH 3	GERMANIUM	----	----	0.80	----	----	0.80
8	LENS CH 3	GERMANIUM	----	----	0.80	----	----	0.94
9	LENS CH 2	GERMANIUM	----	0.92	----	----	0.95	----
10	FILTER CH 2	GERMANIUM	----	0.80	----	----	0.80	----
11	MIRROR CH 2	Au COATED Al	----	0.97	----	----	0.97	----
12	LENS CH 2	GERMANIUM	----	0.92	----	----	0.95	----
13	LENS CH 1	LAKN19	0.90	----	----	0.97	----	----
14	POLARIZER CH 1	BK-7	0.70	----	----	0.70	----	----
15	FILTER CH 1	BK-7	0.85	----	----	0.85	----	----
16	LENS CH 1	LAKN19	0.90	----	----	0.97	----	----
17	LENS CH 1	LAKN19	0.90	----	----	0.97	----	----
SYSTEM TRANSMITTANCE			0.16	0.518	0.357	0.20	0.552	0.494
UNOBSCURED AREA			0.796	0.796	0.796	0.796	0.796	0.796
SYSTEM THROUGHPUT			0.127	0.412	0.284	0.159	0.439	0.393

The classical Cassegrain design for the CTS collector was chosen becasue it easily meets the performance requirement of 0.10-milliradian blur circle over the IFOV. On axis the performance is geometrically perfect and, therefore, gives a diffraction-limited system at all wavelengths. At the center of the sides of the square 6.2-milliradian IFOV, the geometrical spot size is 0.06 milliradian due to coma, and it reaches 0.09 milliradian at the diagonal corners of the IFOV. Other choices are available for the mirror surface figures than the classical parabola-hyperbola combination of the Cassegrain. A RitcheyCretien design, consisting of two hyperbolic mirrors, would have no coma, but would be more expensive and give essentially no improvement in the total system transfer function. This is because the transfer function is not primarily limited by the optics, but rather by the electronics and the IFOV size. A cheaper design of the Dall-Kirkham type with an elliptical primary mirror and a spherical secondary mirror would have too much coma to meet the 0.10-milliradian blur circle size, although the low frequency optical transfer function would not be appreciably degraded.

The f/3 system appears to be an optimum choice on many counts. At speeds faster than f/3, the classical Cassegrain type telescope would have more than 0.10-milliradian of coma over the 6.2-milliradian IFOV. Slower speeds, like f/4 or f/5, would give better performance, but would increase the sensitivity of the telescope to misalignment of the secondary mirror.

By forming an image onto a field stop and then reimaging this onto the detectors, many problems are avoided and a simple system results. The field stop approach automatically makes all the spectral channels fall into perfect spatial registration in object space. Furthermore, a high quality image is only needed at the field stop since the system transfer function is determined by the transfer function at that point in the system. Following the field stop, we are only interested in collecting most of the energy onto the detectors, not in maintaining resolution. This means that relatively simple recollecting optics can be employed without the high performance requirements of the front telescope.

After the field stop, the various spectral channels are split apart by means of dichroic beamsplitters (elements 4 and 5, Figure 3-7). The beamsplitters are in diverging light (f/3 beam) as shown, but do not introduce an objectionable amount of aberration.

Since we are only concerned with energy collection and not MTF at this point, the image quality can be quite coarse compared to the front telescope, and still have most of the energy fall on the detectors (oversized).

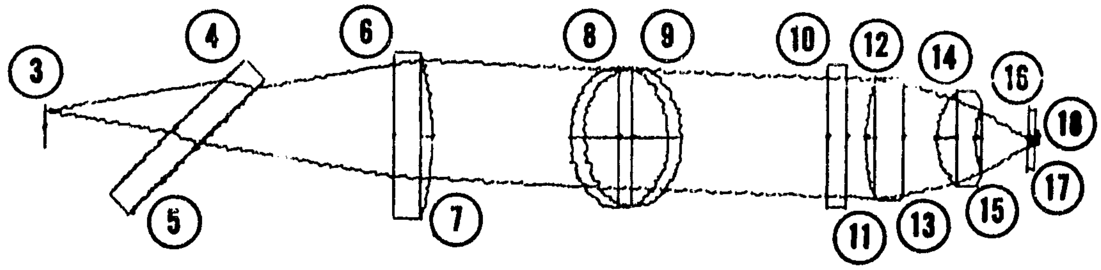
Lenses are used to collimate the light in each channel after the dichroic splitting, and then refocus onto the detectors at f/1.0. Figures 3-8 through 3-10 show the detailed optical train for each of the three channels along with radii and spacing of elements. Two germanium lenses suffice to provide a blur circle size of less than 1/3 of IFOV for the two infrared channels. When integrated over the detector size, this gives almost all of the energy within the IFOV. For the visible channel, much less energy is required because of the sensitivity involved. A smaller portion of the energy is selected from the f/3 diverging beam and focused on the detector by three glass lenses.

Since the light for this channel passes through a dichroic filter (surfaces 4 and 5), which may produce slight polarization, a compensating plate (surfaces 8 and 9) has been added which is tilted about an axis perpendicular to the tilt axis of the beamsplitter. The polarization effects of the compensator will render the final beam unpolarized. Three lenses for glass type LAKN 19 are usedalong with a bandpass filter located in the collimated portion of the beam.

In all three channels, the bandpass filters are situated so as to be easily removable and replaceable if the wavelengths of interest should be rechosen. The germanium lenses have essentially no change in focus as a function of wavelength while the glass lenses for the visible channel already are covering half of the visible spectrum with no problem. Any reasonable wavelength shift will still result in most of the energy falling on the detector.

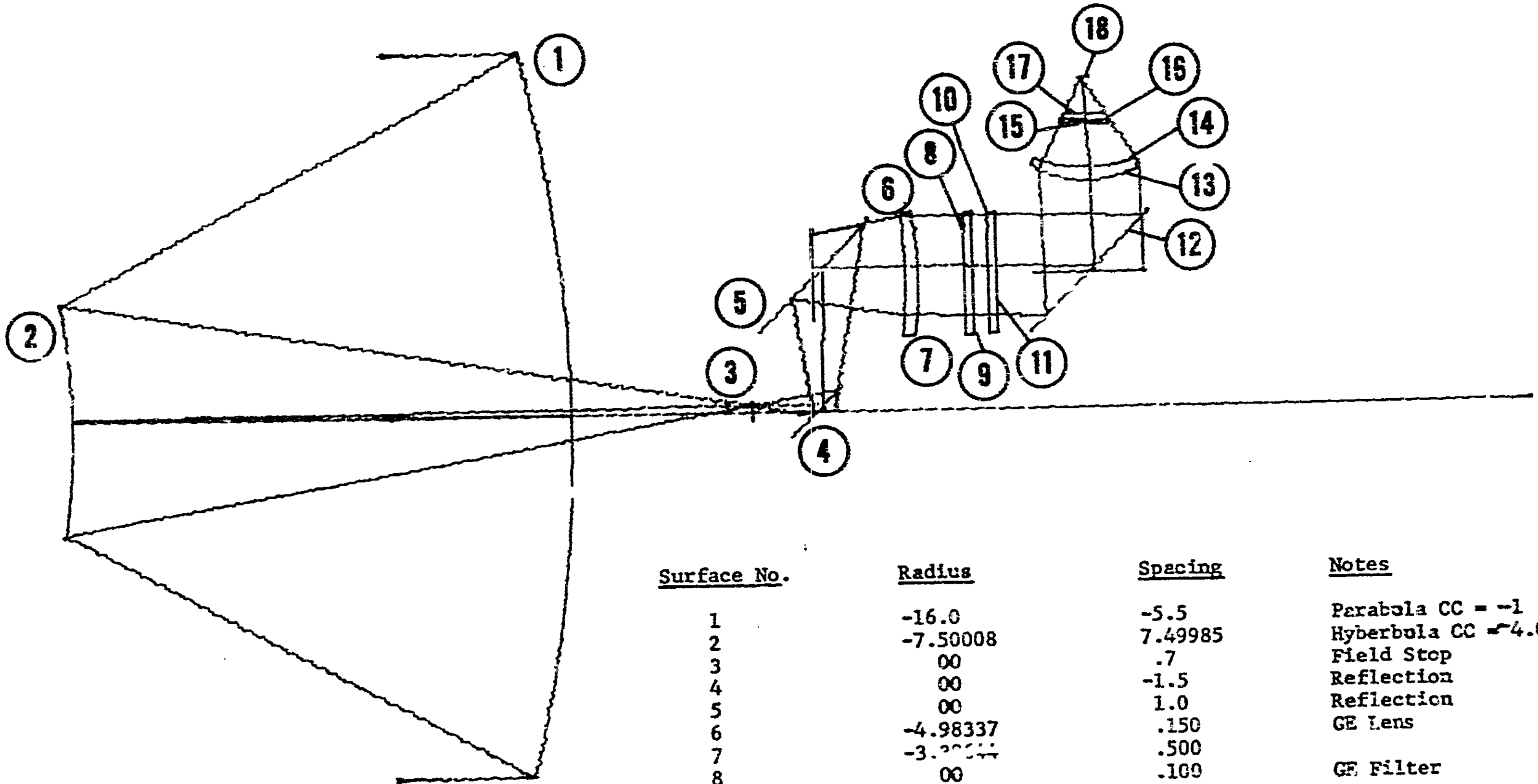
Since the field stop is many times larger than the blur circle diameter, diffraction effects at the edge of the field contribute only a small blurring of the total energy collected. Registration thus largely depends on the electronic delays, which are matched to meet the 0.6 milliradian specification.

Layout of the two infrared channels allows the use of downlooking dewars for the Mercury Cadmium Telluride (Hg,Cd)Te detectors.



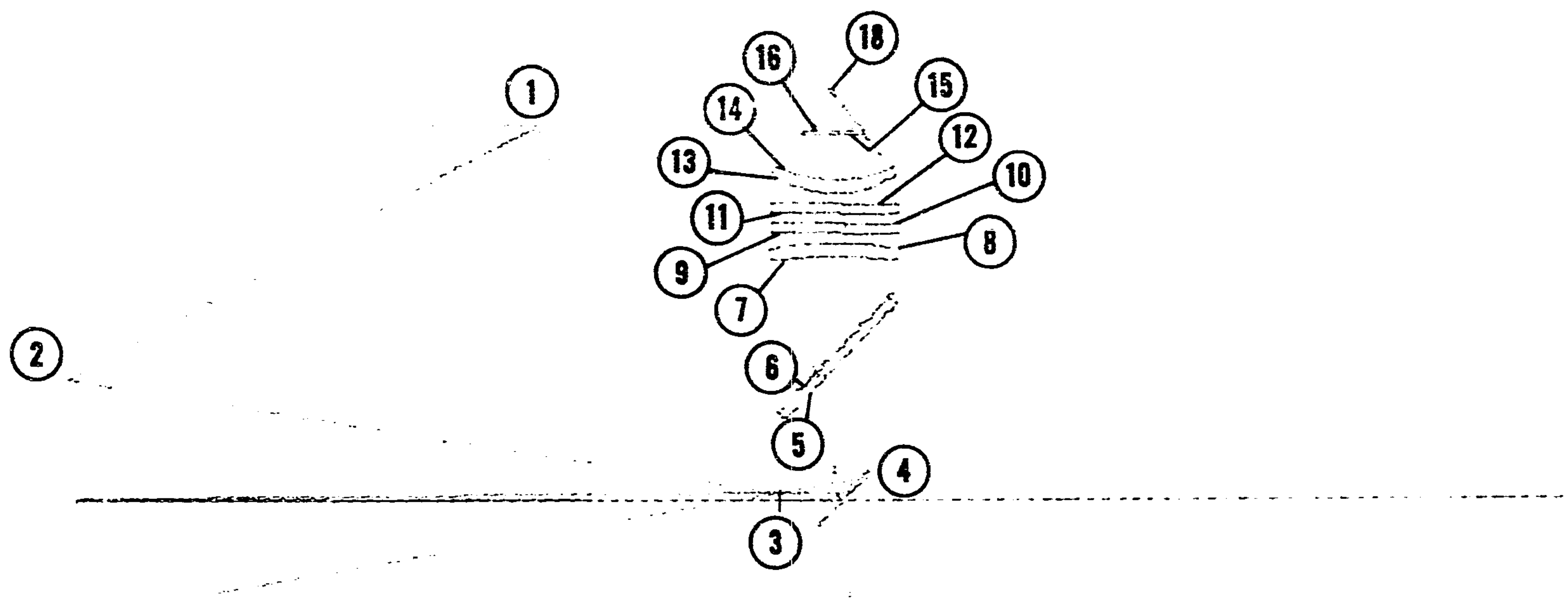
Surface No.	Radius	Spacing	Notes
1	-16.0	-5.5	Parabola CC = -1
2	-7-50008	7.49985	Hyberbola CC =-4.000121
3	00	.7	Field Stop
4	00	.150	Dichroic 45° BK7
5	00	1.0	
6	23.79194	.2	LAKN19 Lens
7	-1.52634	1.0	
8	00	.100	BK7 Compensating Plate
9	00	1.0	
10	00	.100	BK7 Filter
11	00	.100	
12	.98332	.200	LAKN19 Lens
13	18.08393	.17353	
14	.35311	.200	LAKN19 Lens
15	.46156	.28169	
16	00	.040	BK7 Cover
17	00	.010	
18	00		Detector

Figure 3-8 CTS Channel I Optics



Surface No.	Radius	Spacing	Notes
1	-16.0	-5.5	Parabola CC = -1
2	-7.50008	7.49985	Hyberbola CC = -4.000121
3	∞	.7	Field Stop
4	∞	-1.5	Reflection
5	∞	1.0	Reflection
6	-4.98337	.150	GE Lens
7	-3.[illegible]	.500	
8	∞	.100	GE Filter
9	∞	.150	
10	∞	.100	GE Filter
11	∞	1.0	
12	∞	-1.0	Reflection
13	-1.10236	-.150	GE Lens
14	-1.48182	-.500	
15	∞	-.040	GE Window
16	∞	-0.0682	
17	∞	-.37544	Cold Stop
18	∞		Detector

Figure 3-9 CTS Channel 2 Optics



Surface No.	Radius	Spacing	Notes
1	-16.0	-5.5	Parabola CC = -1
2	-7.50008	7.49985	Hyberbola CC = -4.000121
3	∞	.700	Field Stop
4	∞	-1.5	Reflection
5	∞	-.100	GE Dichroic
6	∞	-1.0	
7	4.90304	-.150	GE Lens
8	3.36744	-.1	
9	∞	-.1	GE Filter
10	∞	-.1	
11	∞	-.1	GE Filter
12	∞	-.1	
13	-1.10271	-.150	GE Lens
14	-1.47837	-.500	
15	∞	-.040	GE Window
16	∞	-.23772	
17	∞	-.22133	Cold Shield
18	∞		Detector

Figure 3-10 CTS Channel 3 Optics

3.2.1 Image Quality

Figure 3–11 shows the shape of the image of points at the corners of the IFOV on the detectors at the best focus position. Due to the aberrations present, if the detector were of exactly the size indicated by first-order optics, some radiation would be lost. The loss would increase if the focus were not perfect, and a study was made to determine the collection efficiency for three different detector sizes as a function of focus error. The results, shown in Figure 3–12, led to the selection of an 0.080-inch detector size. This choice gives minimum detector noise while rendering manufacturing tolerances on the dewar fairly loose; at a defocus of 0.020–inches, the system still collects all the radiation.

3.2.2 Cold Shield

An analysis was performed to determine the sources of self-emitted radiation that could reach the detectors. The optical system was ray traced backwards from the detector. At each surface, the ray positions were compared with the clear aperture of that surface, and, if this was exceeded, the intersection point of those rays falling outside the aperture were assumed to represent potential sources of self-emitted radiation. The resulting map of sources, in the coordinate system of the final recollector lens, is shown in Figures 3–13 and 3–14. The dots on these figures represent rays that were transmitted entirely through the telescope, and the numerals indicate which surface interrupted the ray in question. Surface 3 is the final lens mount, surface 14 is the rear surface of the primary micron, and surface 15 represents the secondary mirror; rays stopped there fall outside the clear aperture and are not reflected. Surface 16 is the primary mirror and 17 is the obscuration caused by secondary.

It is evident from Figures 3–13 and 3–14 that considerable flux could originate from surfaces 14 and 15. Since these are forward of the chopper, they would contribute false signal.

In order to eliminate this unwanted radiation, we make use of the fact that the recollector optics forms an image of the primary mirror as well as an image of the distant object. The image for the mirror, called the exit pupil of the system, falls a fraction of an inch in front of the detectors. A baffle may be placed at this location, as shown in

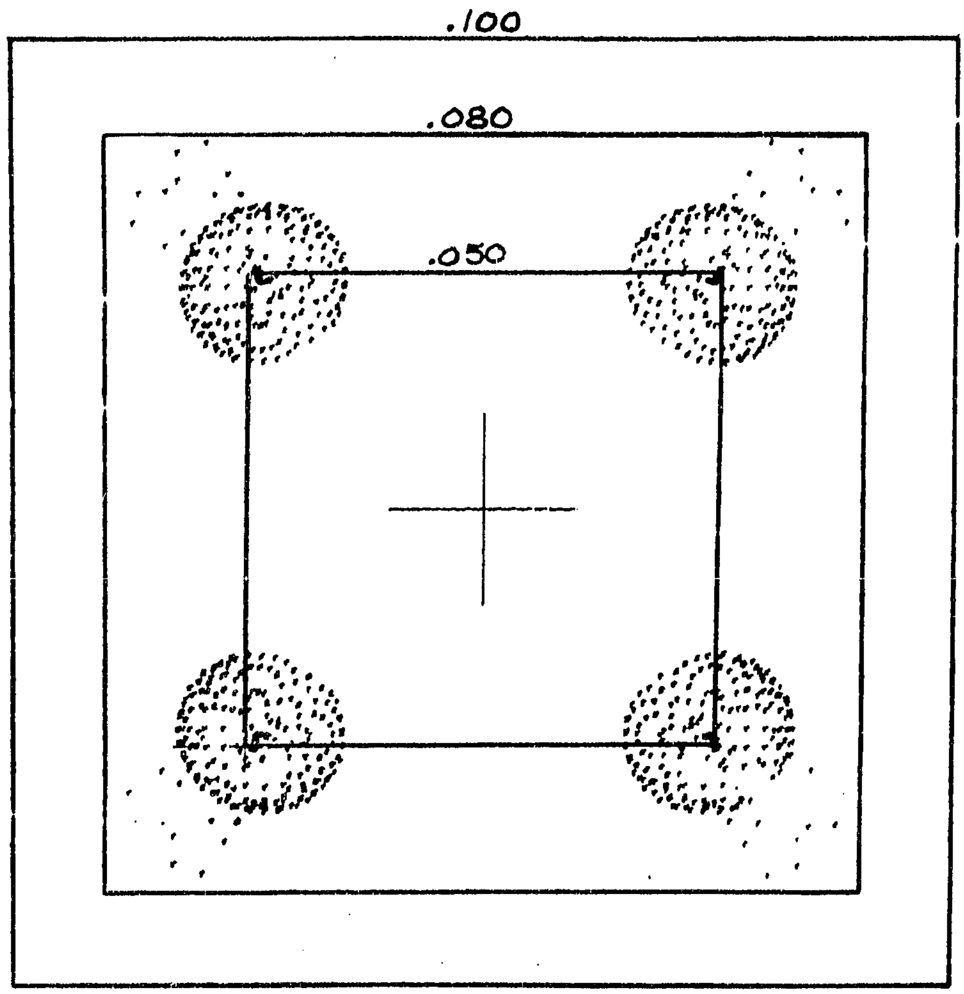


Figure 3-11 CTS Detector Image

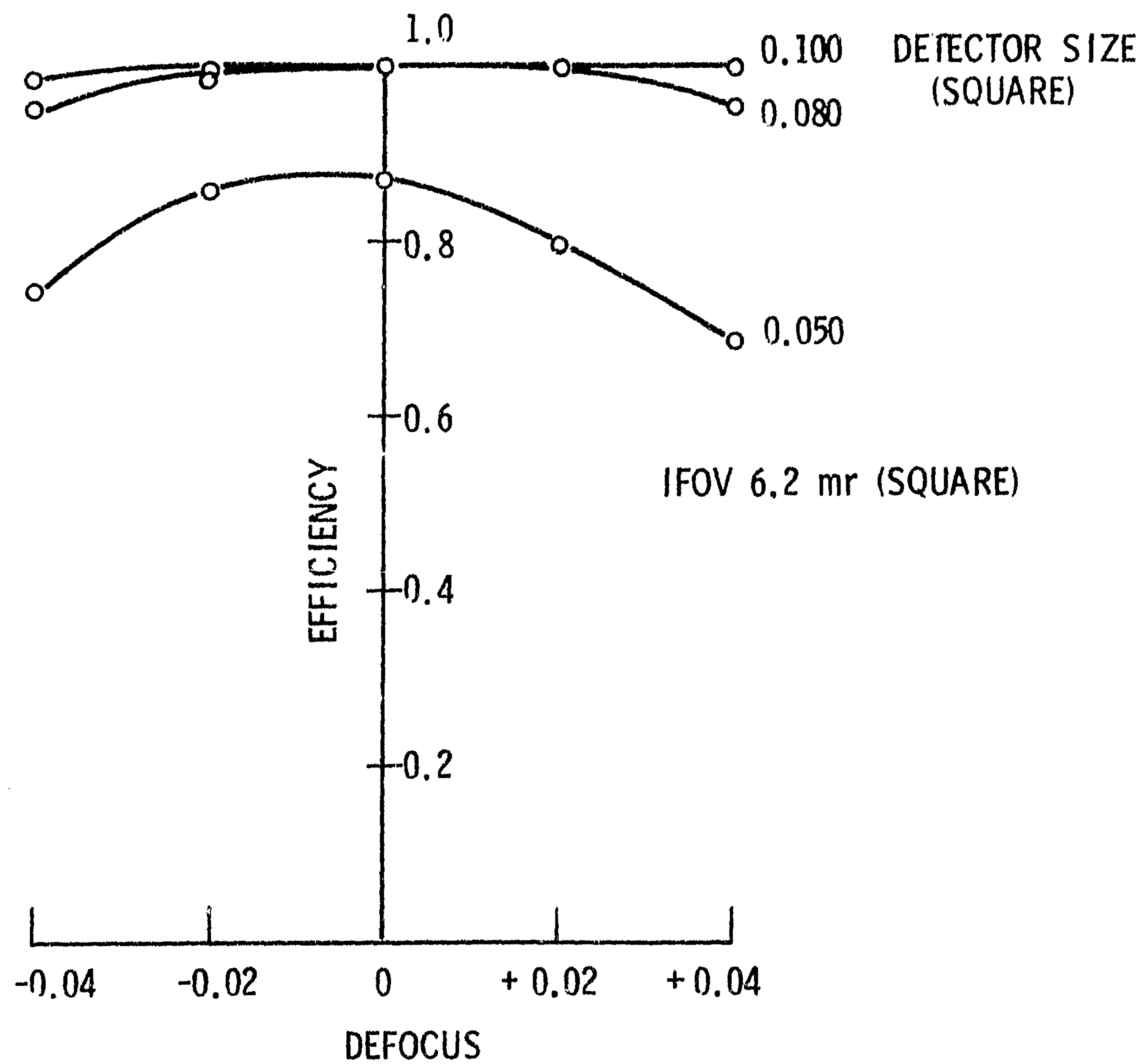


Figure 3-12 CTS Through Focus Efficiency

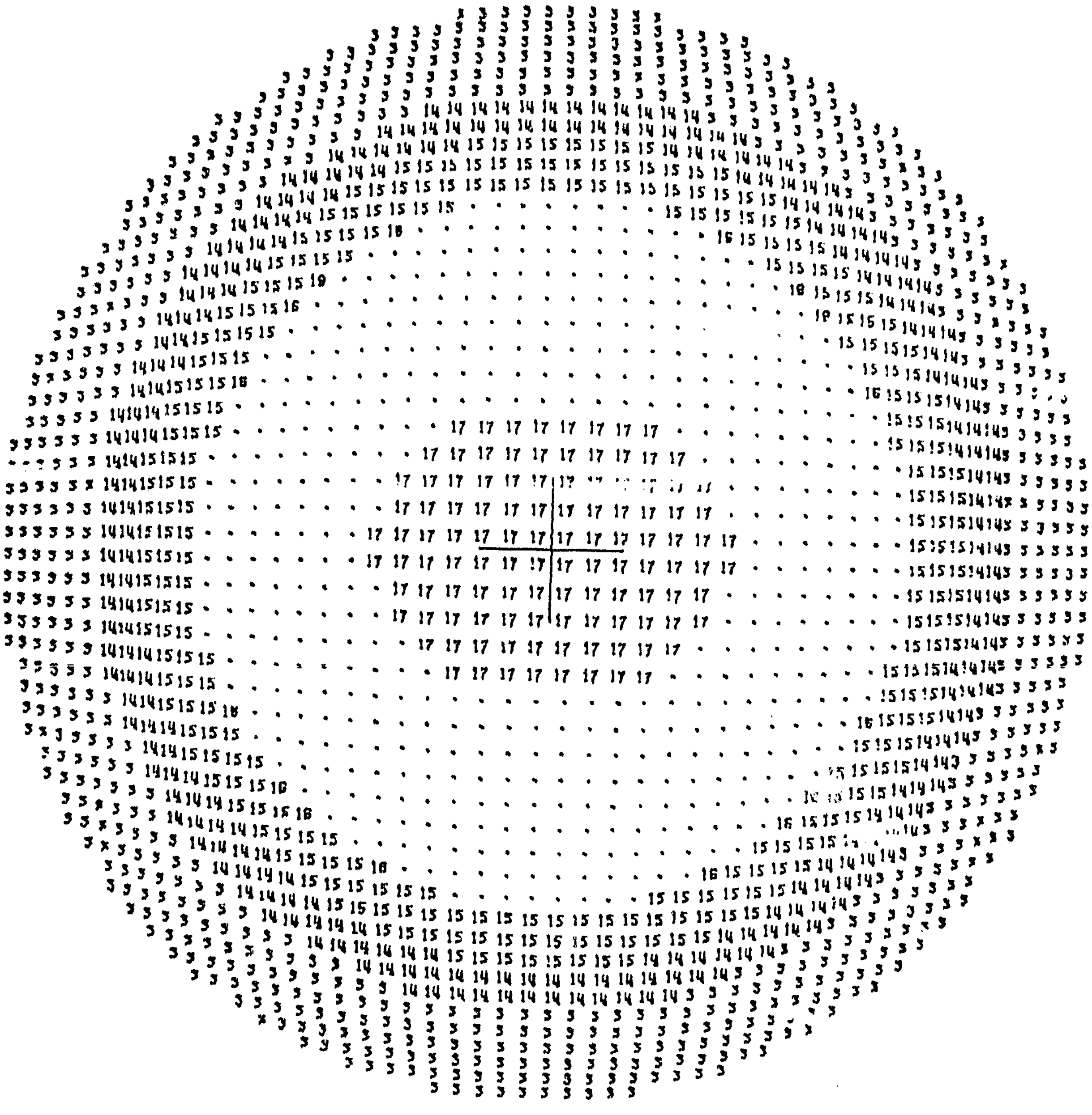


Figure 3-13 Detector Field of View Without Cold Shield

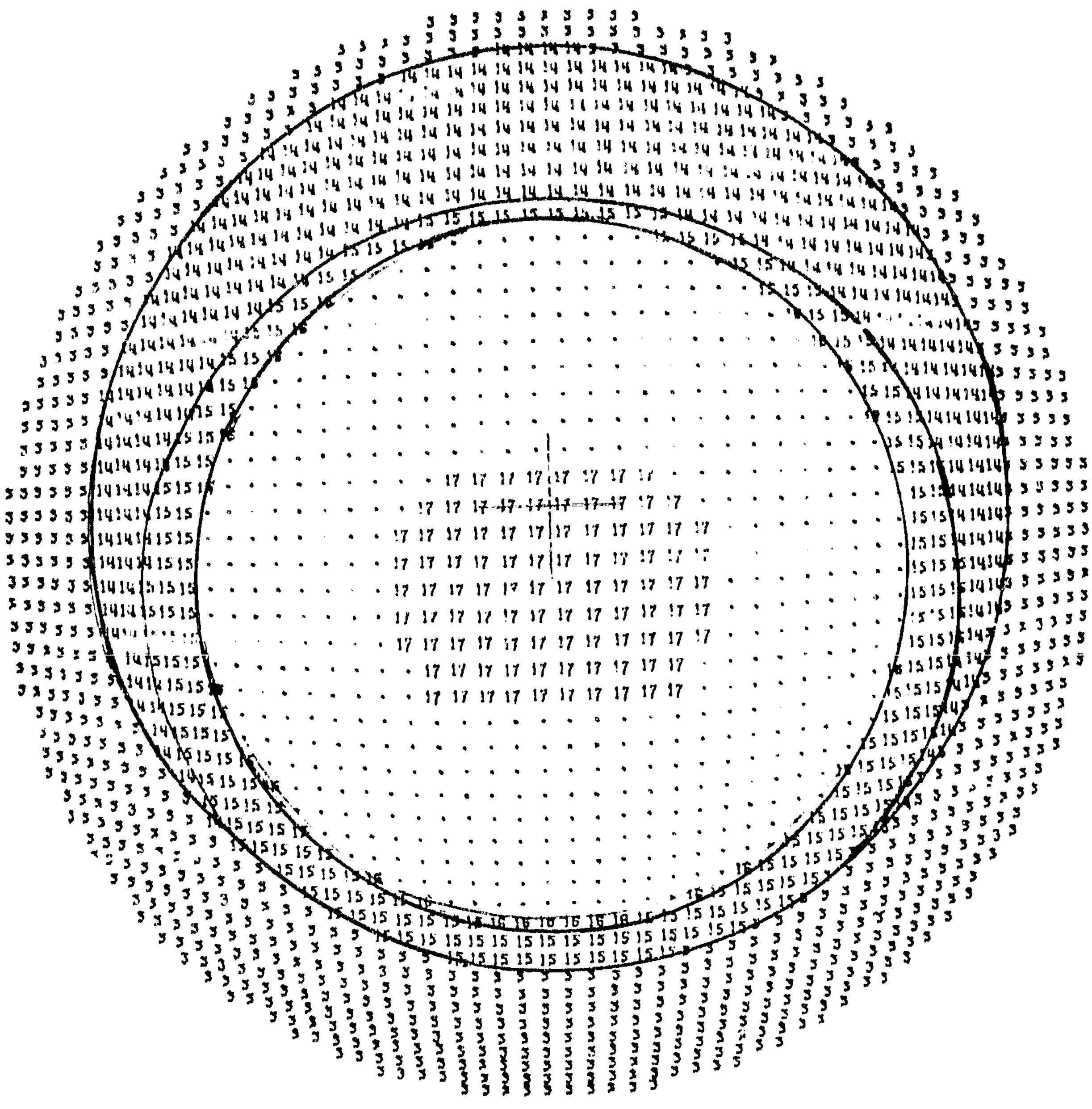


Figure 3-14 Detector Field of View Without Cold Shield

Figures 3–15 and 3–16, which will completely obstruct any self-emitted radiation arriving at the detector from around the outside of the beam. (Stray radiation arriving from within the obscuration cone is unaltered). Since the baffle is behind he chopper, any radiation originating on it is not chopped and does not contribute an ac signal. It is even possible to eliminate most of the signal by cooling the baffle. This is not difficult owing to its location within the dewar, and when this technique is employed it is called a cold stop. The optical effect of the cold stop is shown in Figure 3–17. The only significant sources of radiation indicated are the signal itself (dots), the obscuration (18), and the cold shield (3).

3.2.3 Optical Telescope

A tolerance analysis was performed to determine optical sensitivities to manufacturing and alignment errors. Results of this analysis are summarized in Table 3–6. This table lists the allowable variation from the specification during lens fabrication and system alignment.

3.3 MECHANICAL DESIGN

3.3.1 Mechanical Configuration

Figure 3–18 shows the scanner. Figures 3–19 and 3–20 are side views and rear views of the scanner housing respectively. The main scanner structure consists of a single aluminum casting to which the optics, detectors, chopper, and calibration sources are mounted.

Selection of aluminum for the scanner housing minimizes misalignments due to thermal gradients within the scanner. Since the primary and secondary mirrors are also constructed of aluminum, the telescope remains aligned through the specified -40° C to +40° C temperature excursion range.

Figure 3–21 shows the calibration source location with respect to the optical axis and secondary mirror spider.

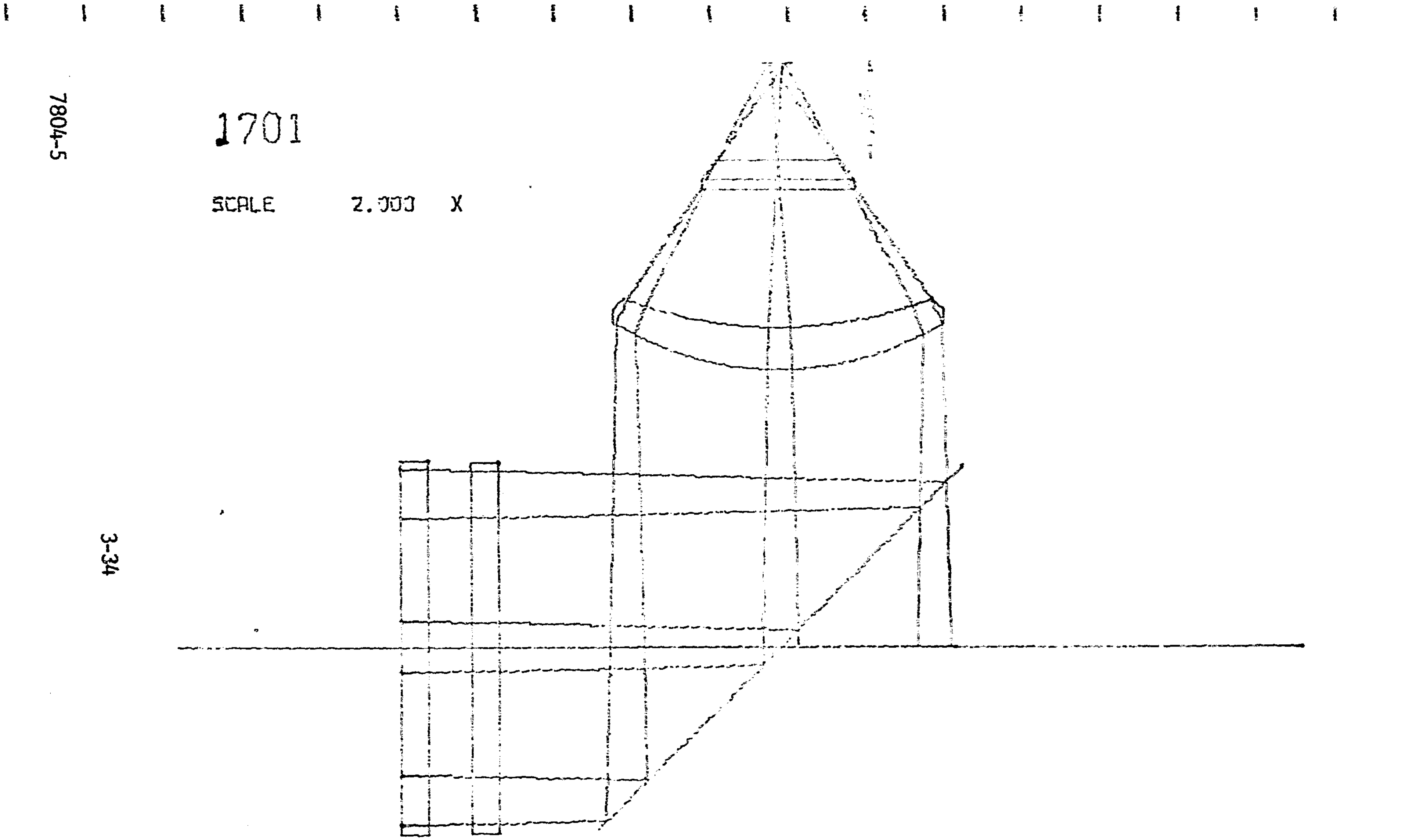


Figure 3-15 Channel 2 Cold Shield

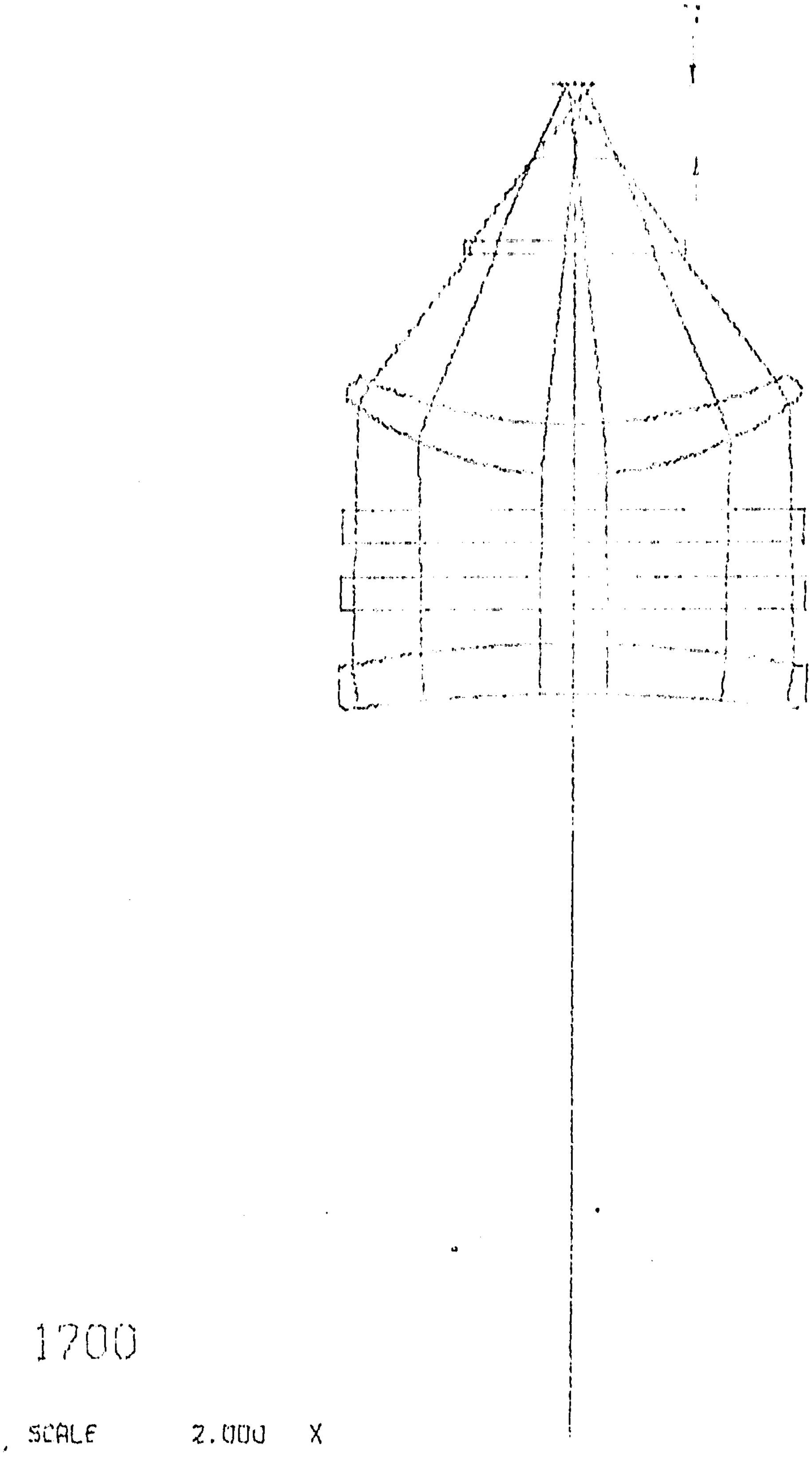


Figure 3-16 Channel 3 Cold Shield

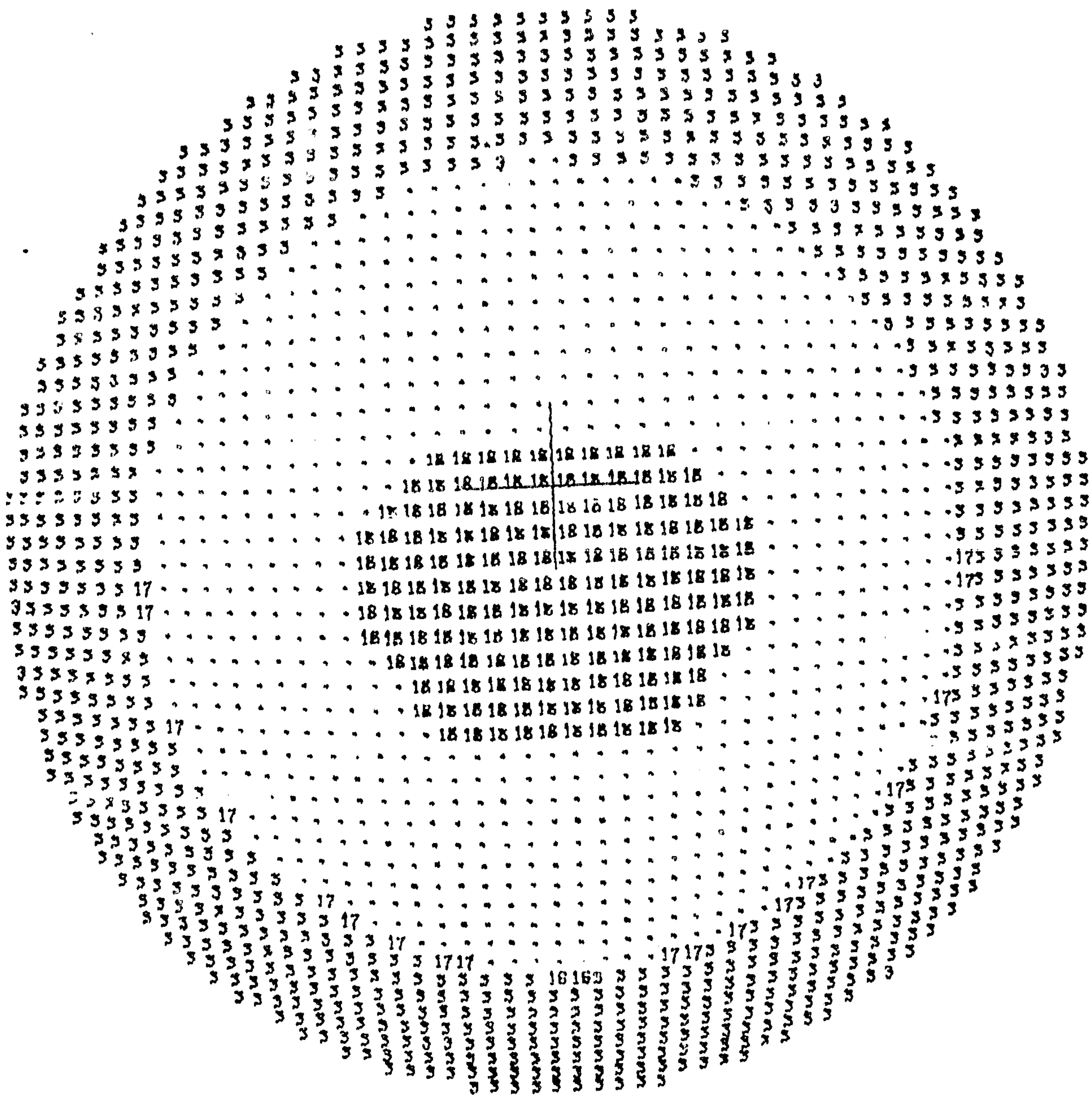


Figure 3-17 Detector Field of View With Cold Shield

Table 3-6 CTS TOLERANCES

FOREOPTICS	M_1, M_2	FIGURE TOGETHER TO NULL AT SPECIFIED BACK FOCAL DISTANCE	
RECOLLECTOR OPTICS	VARIABLE	VALUE	TOLERANCE
	LENS THICKNESS	---	±0.002
	AIR SPACES	---	±0.002
	FILTER THICKNESS	---	+0.010
	T.I.R. (WEDGE)	---	<0.001
	FIGURE	---	5 Fringes to Test Plate, 1/2 Fringe Irreg.
	RADII:		
CH 1	L_1, R_1	23.792	±0.200
	L_1, R_2	- 1.5263	±0.015
	L_2, R_1	0.9833	+0.009
	L_2, R_2	18.0839	±0.180
	L_3, R_1	0.3531	±0.003
	L_3, R_2	0.4616	±0.004
CH 2	L_1, R_1	- 4.9834	±0.040
	L_1, R_2	- 3.3964	±0.030
	L_2, R_1	- 1.1024	±0.010
	L_2, R_2	- 1.4818	±0.010
CH 3	L_1, R_1	4.9030	±0.040
	L_1, R_2	3.3674	±0.03
	L_2, R_1	- 1.1027	±0.010
	L_2, R_2	- 1.4784	±0.010

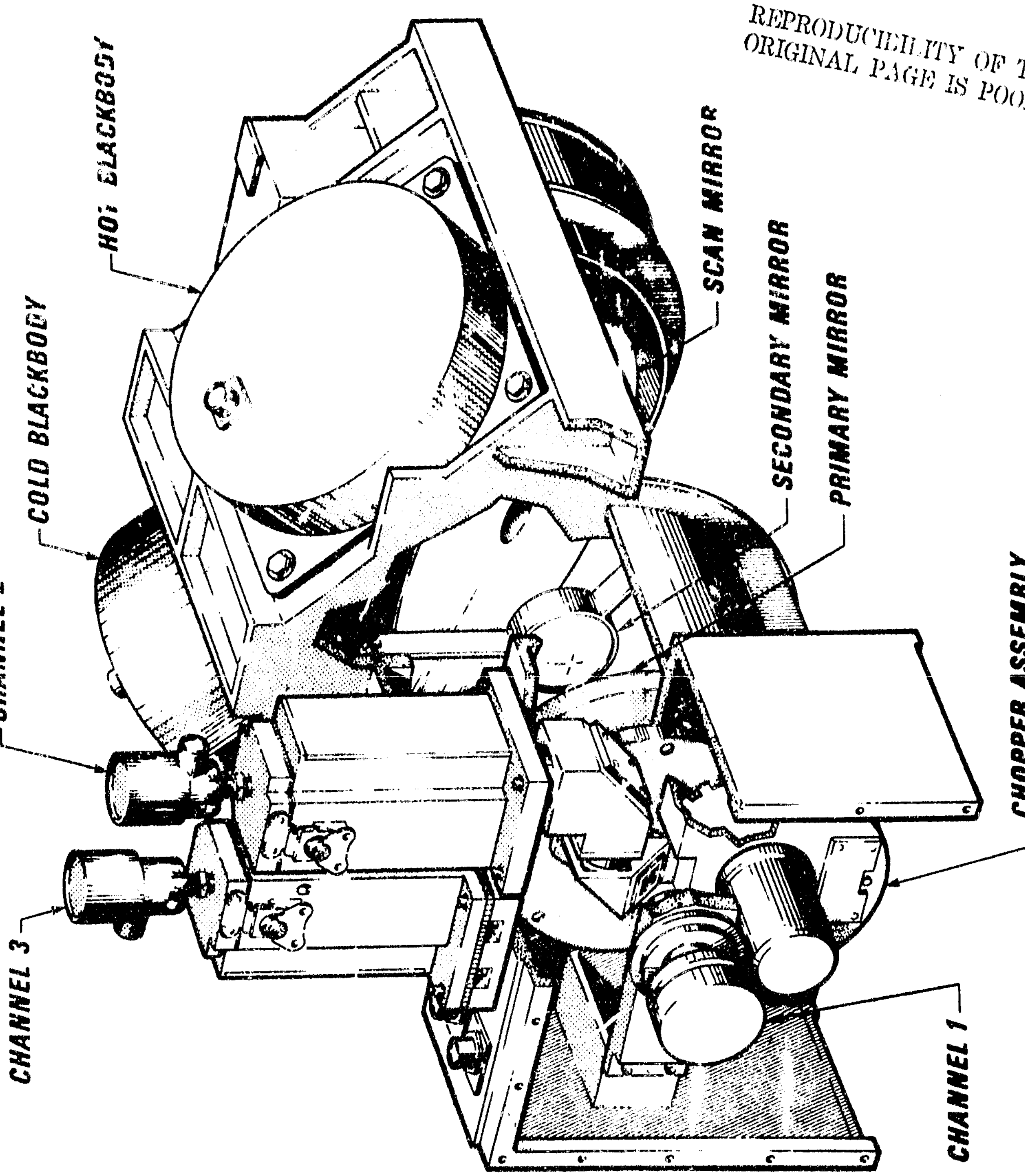


Figure 3-18 Scanner Isometric

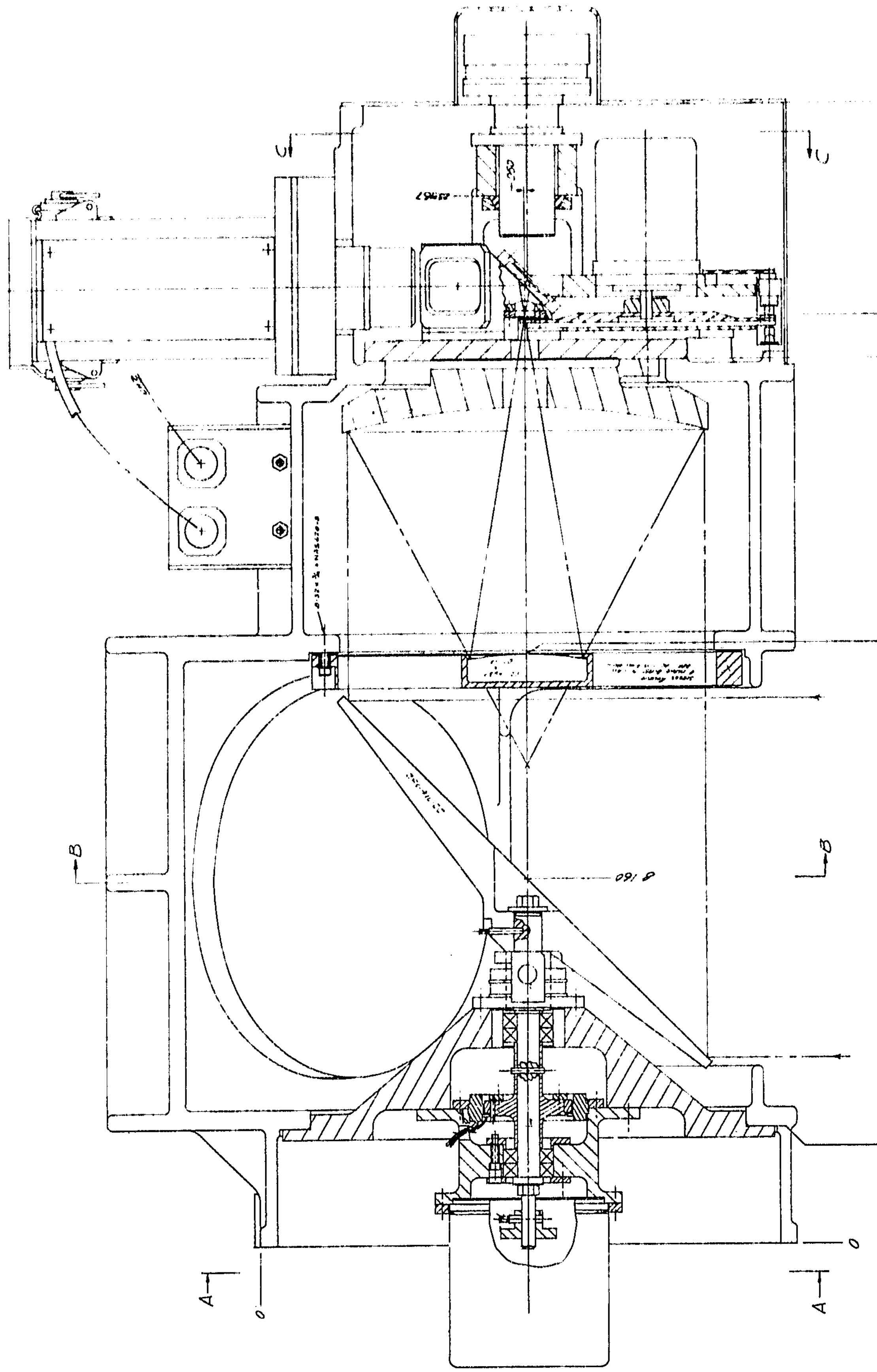


Figure 3-19 Cloud Top Scanner

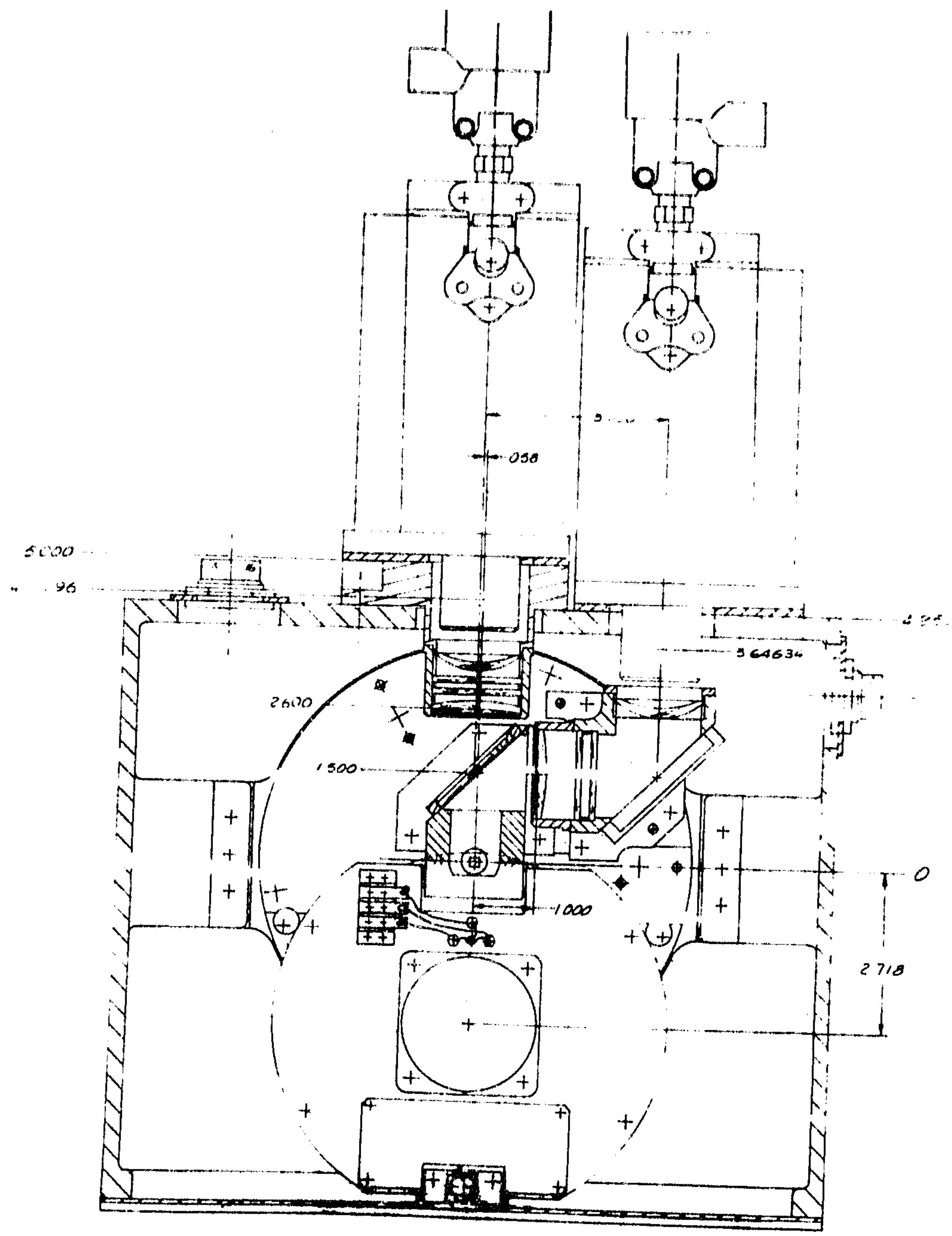


Figure 3-20 Scanner Rear View

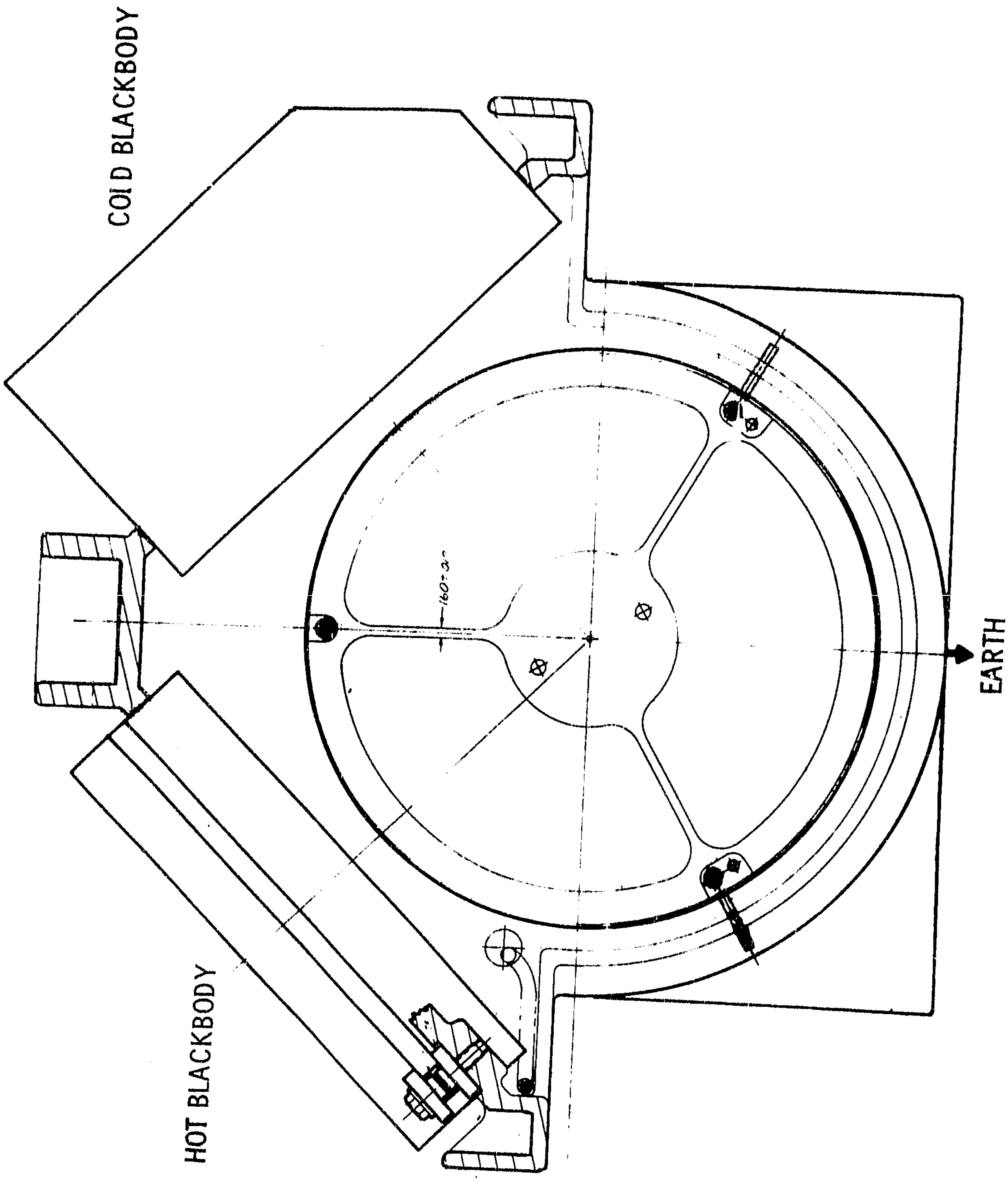


Figure 3-21 Calibration

3.3.1.1 (Hg,Cd)Te Dewars

Figure 3-22 is a detailed drawing of the (Hg,Cd)Te liquid nitrogen (LN_2) dewars and housings for channels two and three. To maximize operating time, glass dewars are used as the LN_2 reservoir. Machined aluminum housings protect the glass dewars from damage and provide alignment surfaces for each detector.

In order to allow extended operation, the dewar well must be maintained at an ambient pressure of one atmosphere. If pressure were reduced, the LN_2 would boil off too quickly thereby shortening operating time. An absolute pressure relief valve mounted on the aluminum housing seals each dewar and maintains pressure within the dewar at 1.2 atmospheres.

3.3.1.2 Visual Detector Mounting

The channel one assembly consists of preamplifiers and optics. All components mount on a support bar shown in Figure 3-23 which is attached to the main casting as shown in Figure 3-18. The center drawing in Figure 3-23 is a cross sectional view of channel 1 optics showing the collimator lens at left, compensator plate positioned at 45 degrees to the optical axis, two recollecting lenses and detector/preamplifier assembly at the extreme right. Transverse alignment of the detector is achieved by translating the detector/ preamplifier assembly, while focus is optimized by selecting the proper shim dimensions for this assembly.

3.3.1.3 Electronics Assembly

Figure 3-24 shows the electronics assembly revealing locations of electronics boards, power supply and connectors. The base is made of a solid aluminum plate to facilitate heat transfer away from the power supply. No fan is provided because at the flight altitude of 60,000 feet air flow would be a very inefficient cooling method. Cooling is, therefore, achieved only by conduction through the base plate.

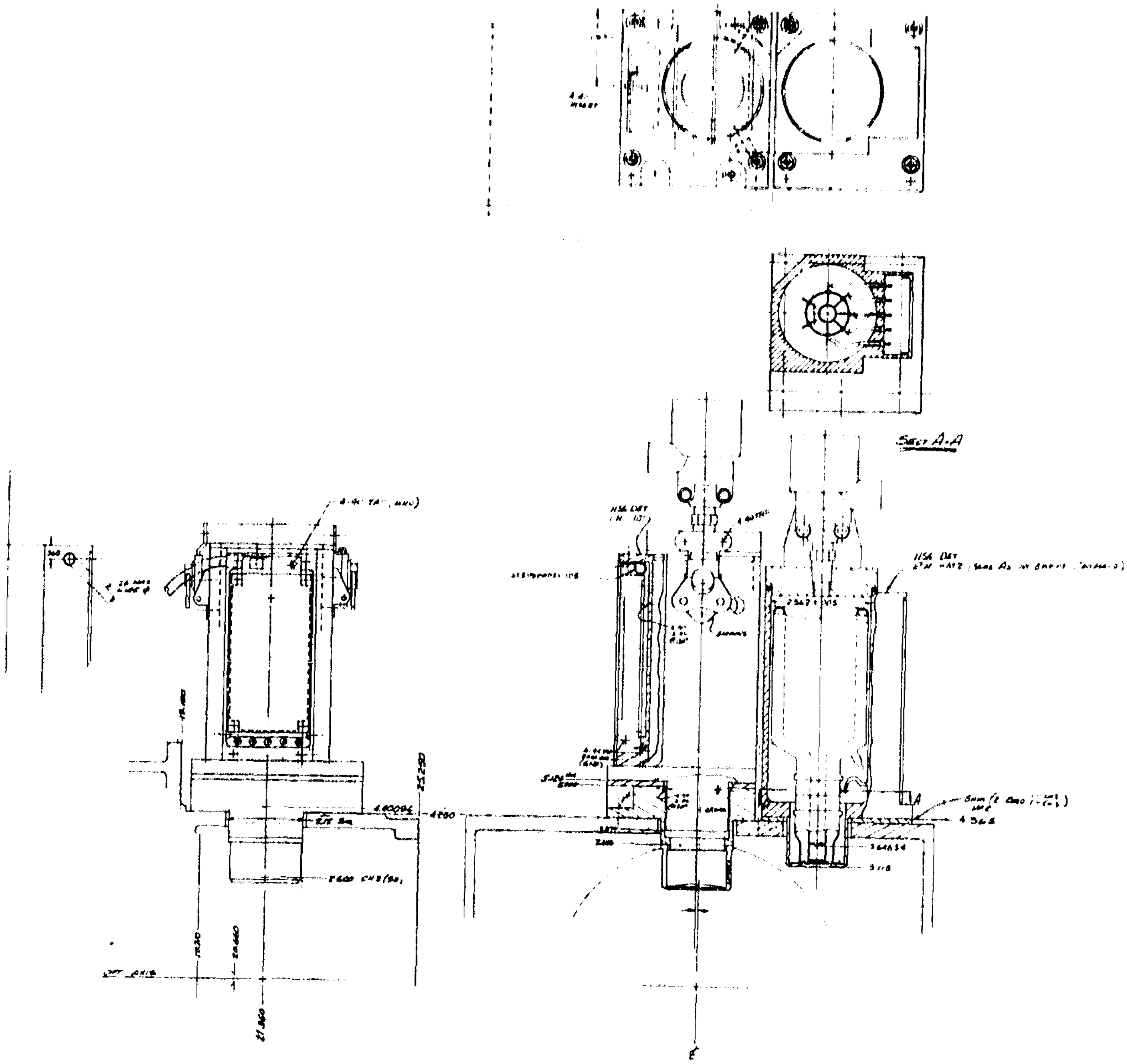


Figure 3-22 Channel #2 and #3 Dewar Assembly

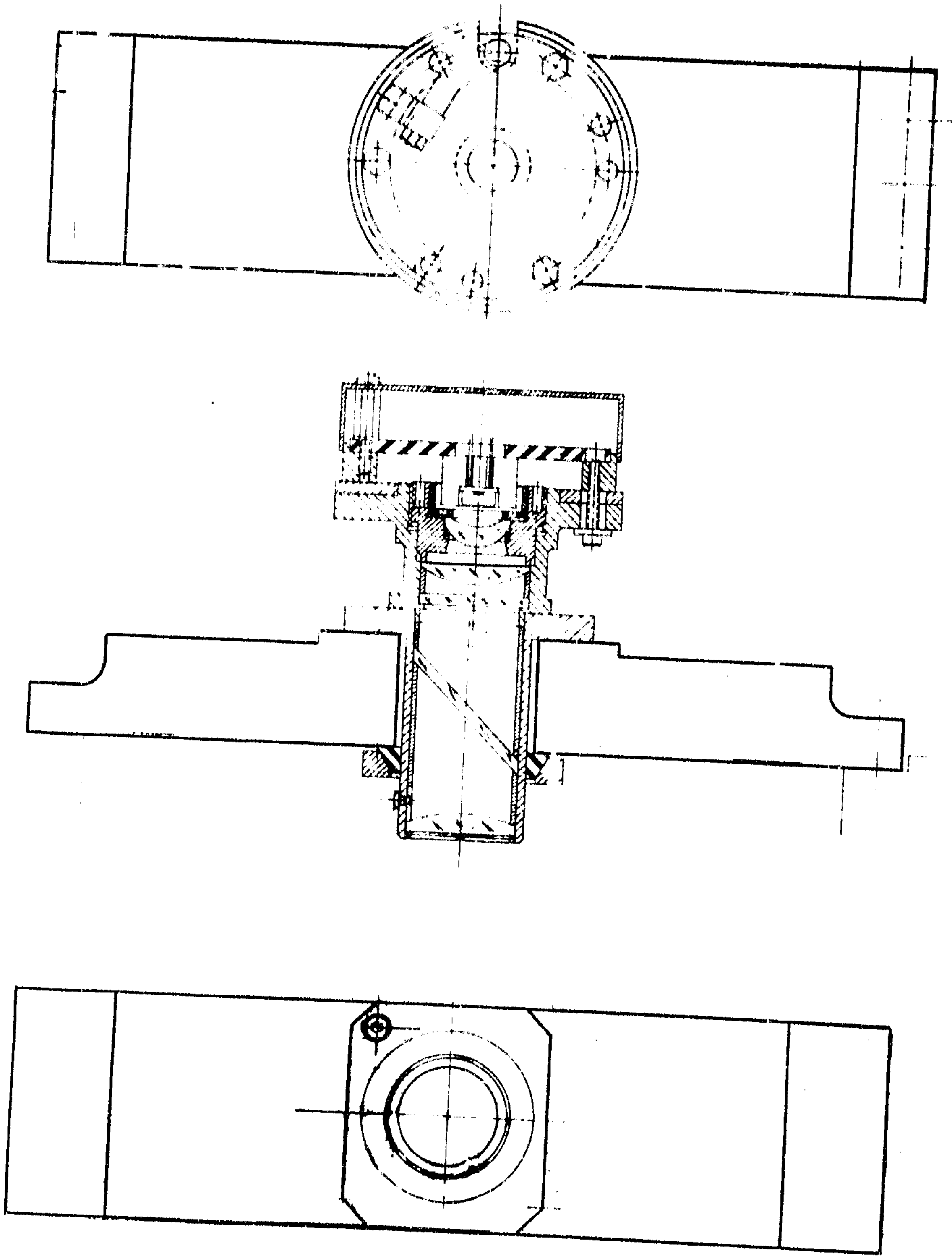


Figure 3-23 Visual Detector

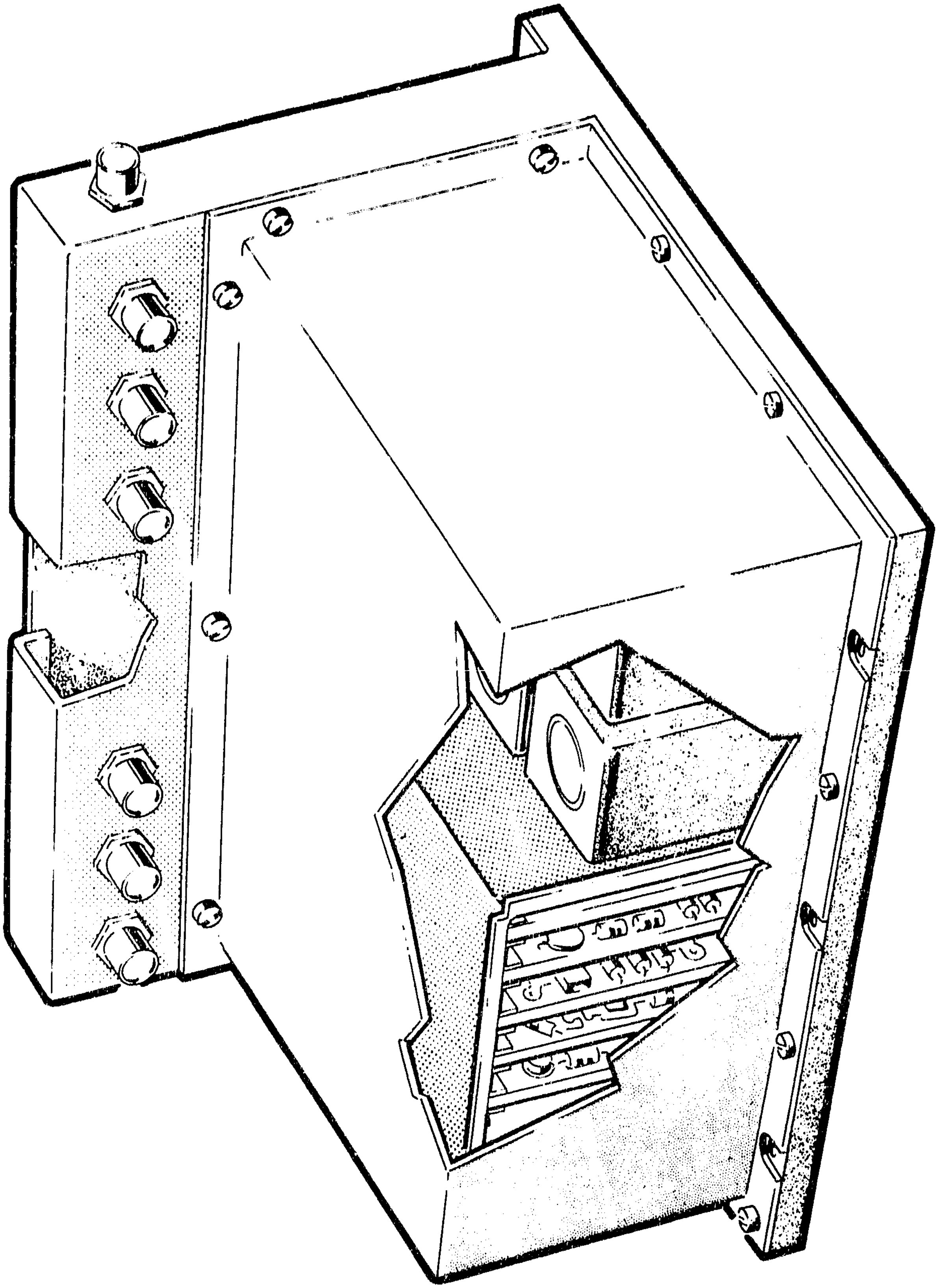


Figure 3-24 Electronics Assembly

Figure 3–25 is an interconnect diagram of the major subassemblies.

3.3.1.4 Sensor Mounting

Mounting of the sensor within the aircraft POD is shown in Figure 3–26.

3.3.2 Thermal Analysis

A thermal analysis was performed to determine the extent of thermally induced misalignment.

Operation under steady state conditions was analyzed and effects of thermal gradients were investigated. Results of the steady state analysis are given in Table 3–7 showing the expected operational temperatures of elements which can influence radiometric or optical performance. These temperatures are calculated for operation at an altitude of 60,000 feet. The analysis indicated that gradients listed in Table 3–7 have negligible effects on optical and radiometric performance.

In order to determine the need for condensation protection, the instrument temperature profile during descent was calculated as a function of altitude and compared to the dew point. Figures 3–27 and Table 3–8 give results of this calculation. It was determined that by locating blanket heaters in locations described by Table 3–8 condensation can be prevented from forming on critical optical components provided the descent time is longer than 45 minutes.

3.3.3 Structural Analysis

Performance of the CTS system was analyzed for 19 sinusoidal vibration levels and a frequency range of 10 Hz to 2000 Hz. These are worst case conditions for operation at 60,000 feet. Figure 3–28 shows the structural model used to evaluate performance of the scanner assembly. Vibration stresses and deformations due to spin effects on the scan mirror have been calculated and results given in Table 3–9. It can be seen that sufficient

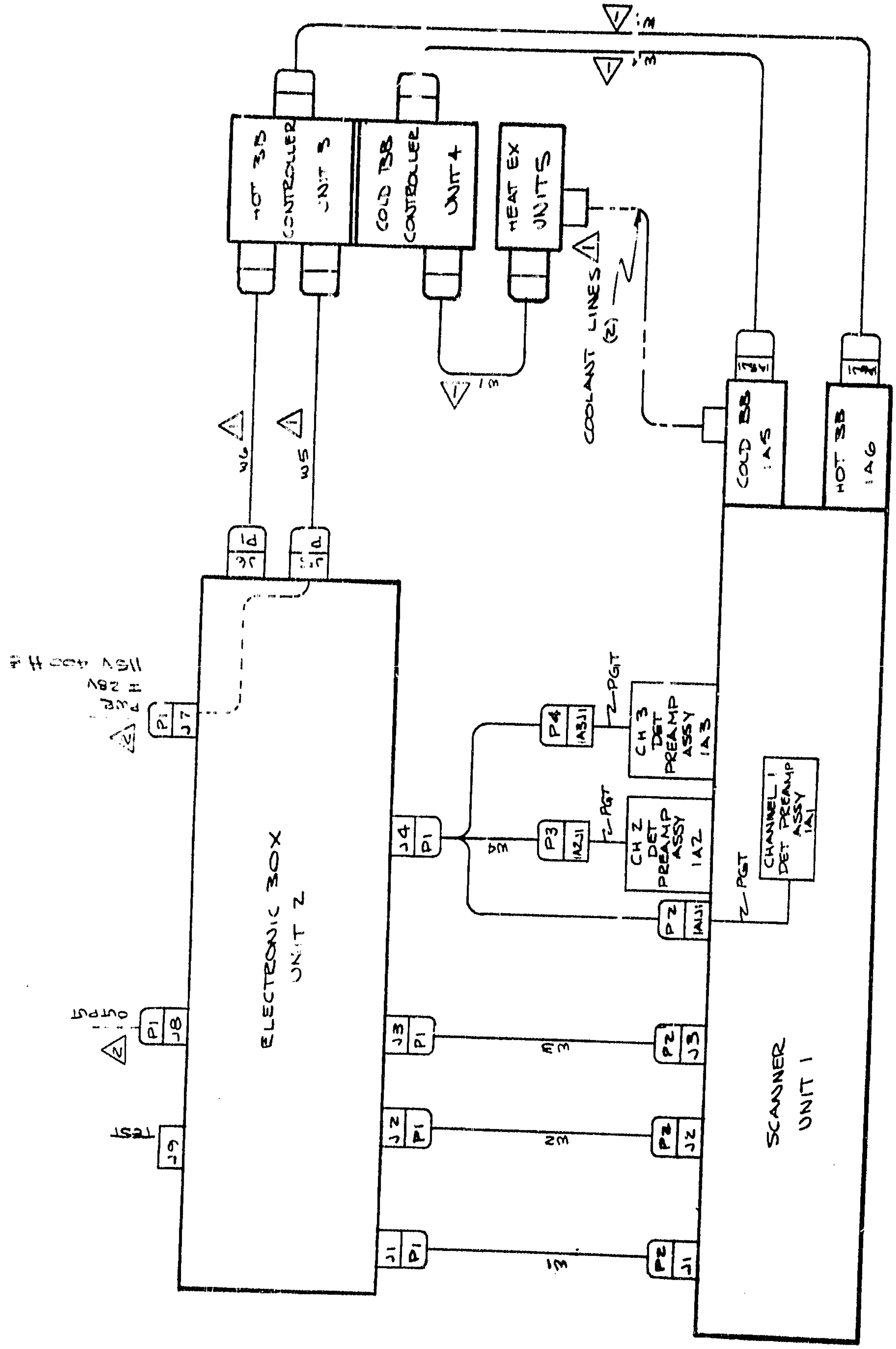


Figure 3-25 Systems Interconnect Diagram

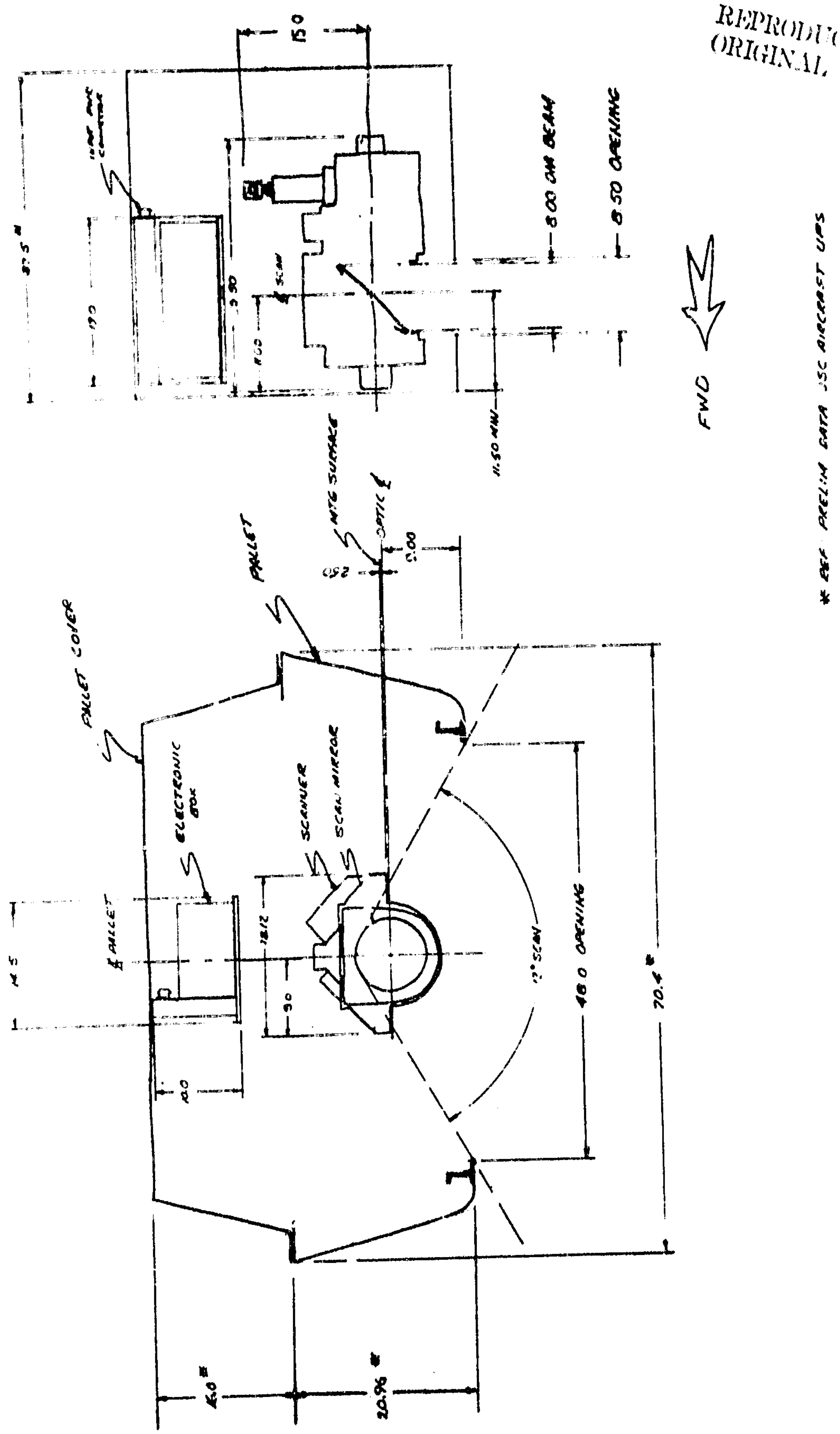


Figure 3-26 Aircraft Mounting

Table 3-7 CLOUD TOP OPERATIONAL TEMPERATURES POD AIR TEMPERATURES

COMPONENT	TEMPERATURE - K
• SCAN MIRROR	266
• SCAN ELECTRONICS	264
• SECONDARY MIRROR	256
• TELESCOPE	257
• PRIMARY MIRROR	259
• CHOPPER MOTOR	266
• CHOPPER BLADE	257
• TORQUE MOTOR AND ENCODER	287
• DETECTOR AND OPTICS SECTION	257

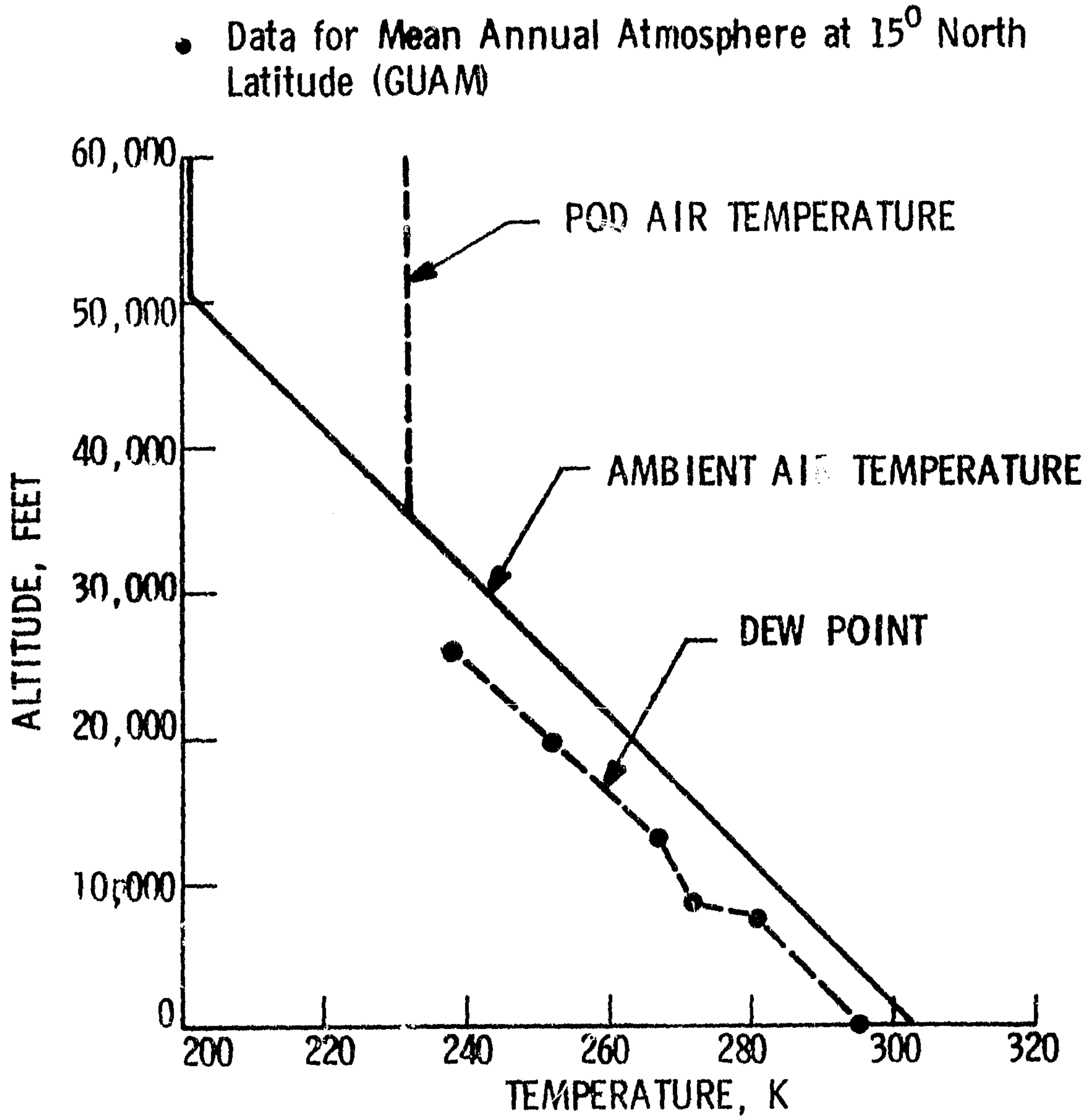


Figure 3-27 Cloud Top Scanner Environmental Conditions

Table 3-8 COMPONENT TEMPERATURE VS AIRCRAFT DESCENT TIME

	HEATER POWER (watts)	COMPONENT TEMPERATURE			
		INITIAL 0.0 hours	DESCENT TIME 0.5 hour	DESCENT TIME 0.75 hour	DESCENT TIME 1.0 hour
SCAN MIRROR	58	256	295	315	334
SECONDARY MIRROR	15	256	300	319	337
PRIMARY MIRROR	0	256	283	299	315
TELESCOPE	156	256	291	307	323
DETECTOR AND OPTICS	156	256	290	306	322
SERVO	125	263	312	330	340

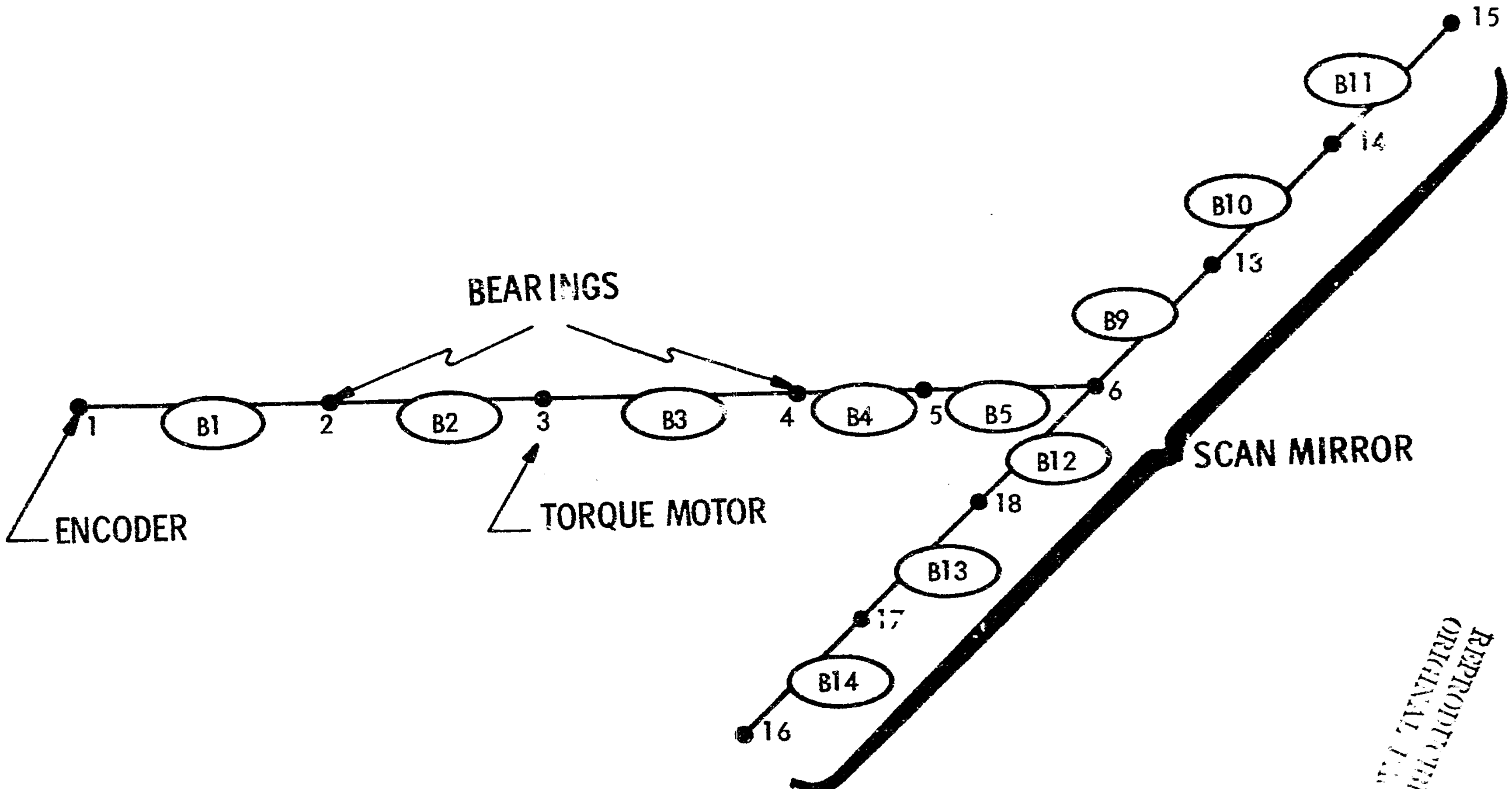


Figure 3-28 CTS Scan Assy, Structural Model

Table 3-9 CTS 1G VIBRATION STRESSES

MATERIAL	LOCATION	MAXIMUM STRESS, PSI	SAFETY FACTOR*
CRES A-286	SCAN SHAFT	9880	3.04
ALUMINUM	B.B. FRAME	5030	3.78

(* = VS MICROYIELD STRESS, CTS OPERATING IN SCAN LOCK)

CTS SPIN EFFECTS (NO VIBRATION LOADS)

MATERIAL	LOCATION	MAXIMUM STRESS, PSI	MIRROR TILT, $\widehat{s}$	SAFETY FACTOR*
CRES A-286	SCAN SHAFT	288	8.49	104.2

(* = VS MICROYIELD STRESS)

design margins exist to insure undegraded performance. Natural frequencies of various components were also calculated so that excessively large resonances could be eliminated. Tables 3–10 and 3–11 give results of these calculations and also list frequencies which were attenuated during vibration testing.

3.4 ELECTRONIC DESIGN

Figure 3–29 is a block diagram of the CTS electronics. The scene radiance, scanned by a rotating mirror, is modulated by a chopper blade and viewed by two (Hg,Cd)Te detector and one silicon detector. Three preamplifiers provide sufficient gain so that the video signals can be efficiently transmitted to post processing electronics located in the electronics assembly. Here video processors synchronously demodulate each signal, filter it through a low-pass filter and format the video and housekeeping information for output to video recorders. Also included in the electronics assembly are power supplies, chopper and scan motor control electronics, and housekeeping buffer electronics.

3.4.1 Video Format

In Figure 3–30 is a video timing diagram as a function of scan angle. The composite video line consists of 120 degree active scan video. This is the time during which scene is viewed. Following are five levels of electronic calibration signal, each 3.6 degrees wide. Ten housekeeping levels described in the following paragraphs occur immediately after the electronics calibration signals. During the last 120 degrees of each scan line both blackbody calibration signals are displayed. Also in the portion of the scan is included a provision for visual calibration, although no visual source has actually been incorporated in the scanner.

The video sync line and video gates are signals generated directly by the encoder and are accessible by way of a test connector in the bench checkout unit.

A listing of housekeeping signals included within each scan line of composite video is given in Table 3–12. Analog signals listed in the same figure are available as individual outputs and can each be monitored.

Table 3-10 CTS NATURAL FREQUENCIES

MODE	FREQ, HZ	PARTICIPATION FACTORS			GENERALIZED WEIGHT LBS	MODE
		X1	X2	X3		
1	149.7	-0.002	0.007	0.76	0.56	X3 TRANSLATION OF SCAN MIRROR DUE TO SHAFT BENDING
2	162.0	-0.085	0.90	-0.013	0.17	X2 TRANSLATION OF SCAN DUE TO SHAFT BENDING
3	233.1	-0.17	1.11	0.51	24.1	X2 BLACKBODY
4	285.3	-0.23	0.85	-0.71	16.4	X2 BLACKBODY
5	362.6	1.33	1.60	-0.001	10.0	X1 SCAN ASSEMBLY
6	376.3	0.046	-0.026	1.47	1.1	
7	410.6	-0.22	0.18	0.27	31.3	
8	467.8	-0.92	0.26	-0.17	61.7	
9	504.9	-1.0	0.077	0.10	26.0	
10	561.1	0.73	0.33	-0.33	19.3	

Table 3-11 CTS IG VIBRATION DEFORMATIONS

(CTS OPERATING IN SCAN LOCK)

OPTICAL COMPONENT	OPTICAL BUDGET	VIBRATION DEFORMATION						MIN. SAFETY FACTOR *
		F = 149.7 Hz			F = 162 Hz			
		EXCITATION DIRECTION			EXCITATION DIRECTION			
		X1	X2	X3	X1	X2	X3	
SCAN MIRROR DECENTER, X2	--	0.21 mils	2.23 mils	0.01 mils	0.78 mils	8.37 mils	0.03 mils	--
SCAN MIRROR DECENTER, X3	--	0.00 mils	0.02 mils	8.31 mils	0.00 mils	0.00 mils	3.86 mils	--
SCAN MIRROR TILT, θ_{X2}	30.9 $\widehat{s}$	0.00 $\widehat{s}$	0.27 $\widehat{s}$	143 $\widehat{s}$	0.00 $\widehat{s}$	0.00 $\widehat{s}$	24.1 $\widehat{s}$	0.22
SCAN MIRROR TILT, θ_{X3}	30.9 $\widehat{s}$	6.7 $\widehat{s}$	78.8 $\widehat{s}$	0.27 $\widehat{s}$	34.1 $\widehat{s}$	296 $\widehat{s}$	1.28 $\widehat{s}$	0.10
SEC. MIRROR TILT, θ_{X2}	180 $\widehat{s}$	0.04 $\widehat{s}$	0.10 $\widehat{s}$	0.02 $\widehat{s}$	0.01 $\widehat{s}$	0.00 $\widehat{s}$	0.03 $\widehat{s}$	1800
SEC. MIRROR TILT, θ_{X3}	180 $\widehat{s}$	0.19 $\widehat{s}$	0.78 $\widehat{s}$	0.01 $\widehat{s}$	0.02 $\widehat{s}$	0.23 $\widehat{s}$	0.12 $\widehat{s}$	231
SCAN MIRROR FIGURE	3 λ	5.8 λ	20.8 λ	0.07 λ	11.7 λ	76.6 λ	0.36 λ	0.04

(*SAFETY FACTOR 1.0 INDICATES UNACCEPTABLE PERFORMANCE)

SUGGESTED VIBRATION SPEC

10-120 Hz 1g
120-180 Hz 0.2g (PREFER ELIMINATE 120-180 Hz)
180-2000 Hz 1g

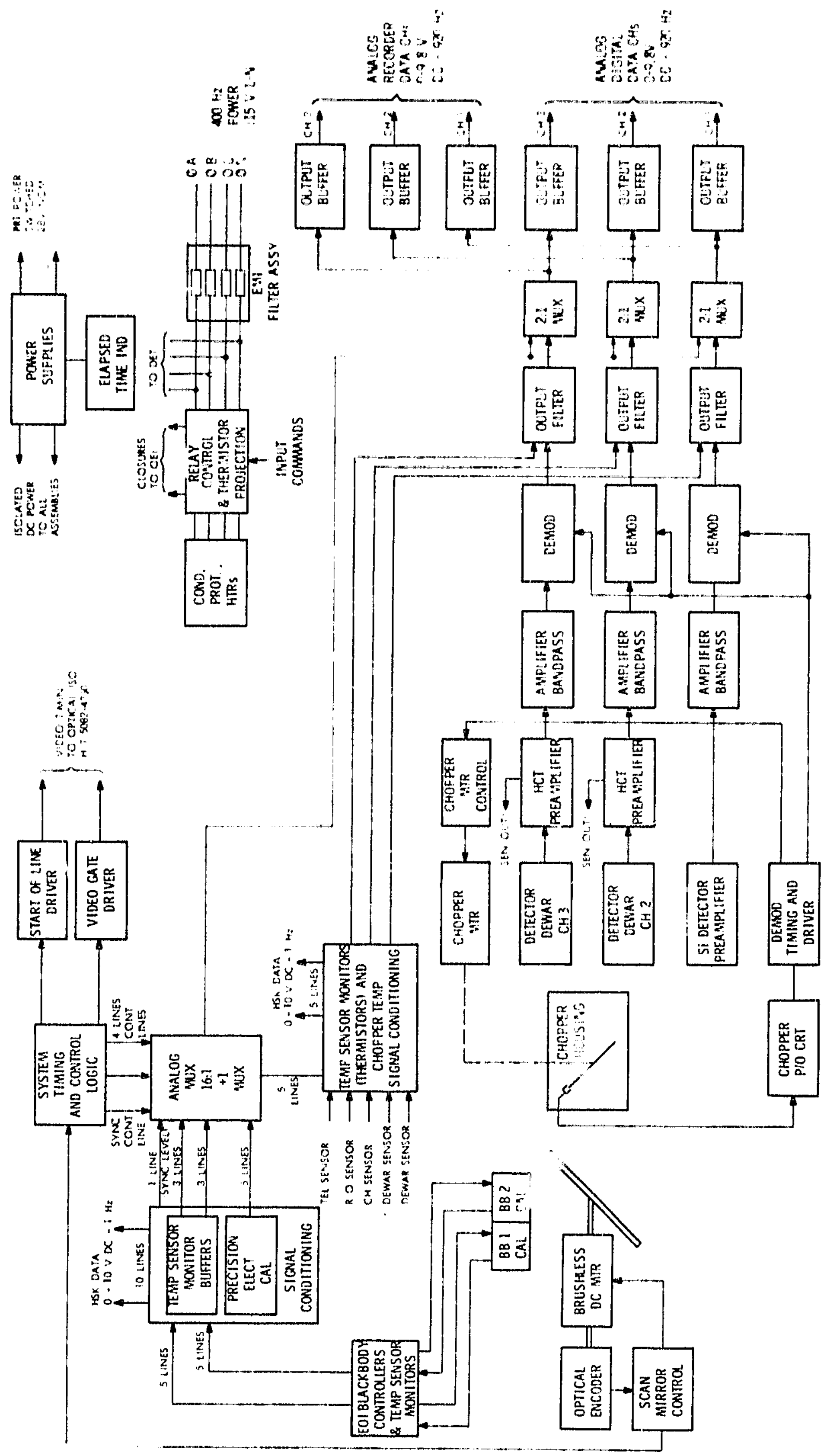


Figure 3-29 CTS Electronic Block Diagram

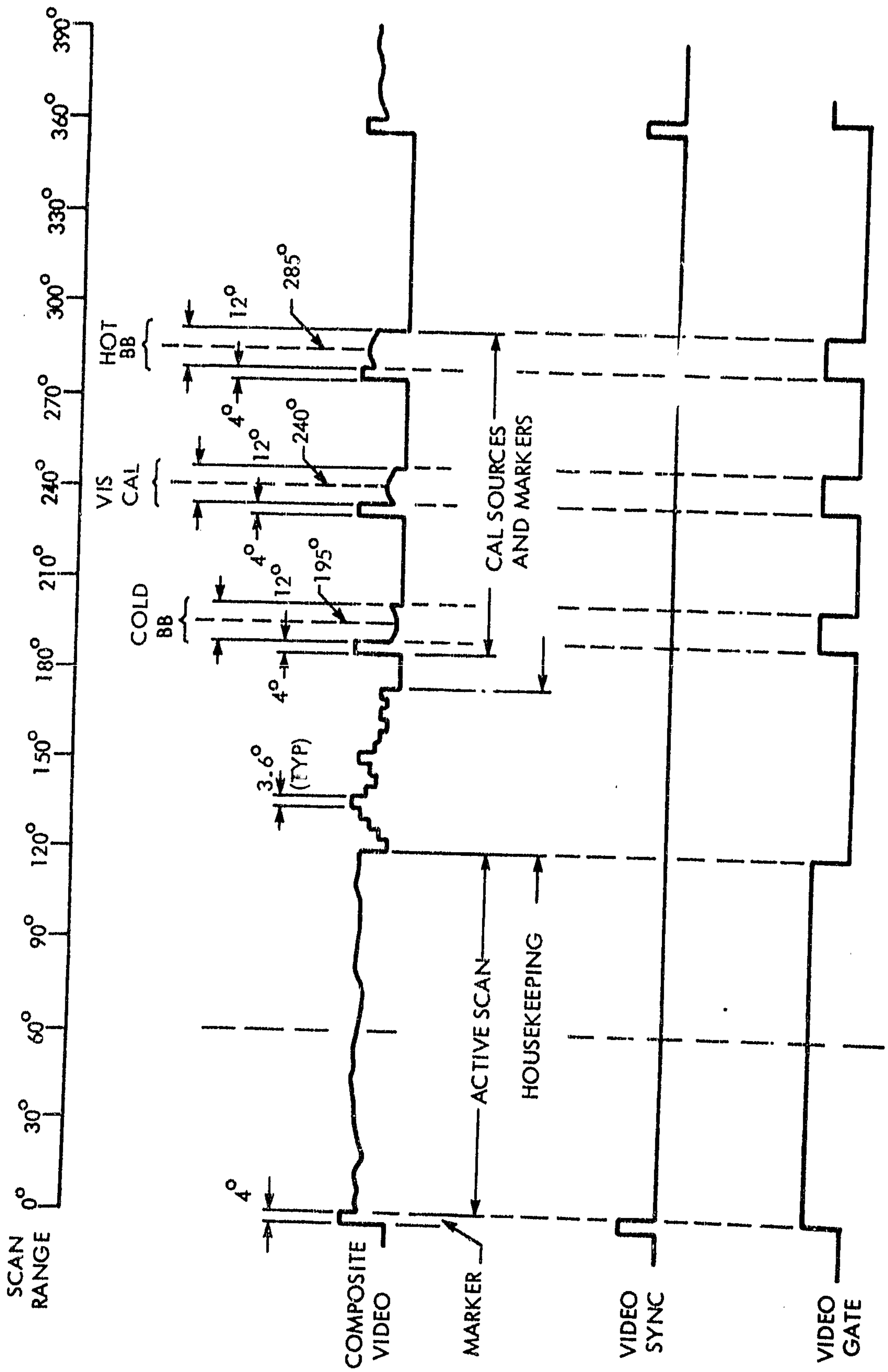


Figure 3-30 Video CTS Timing Diagram

Table 3-12 HOUSEKEEPING FUNCTIONS SUMMARY

COMPOSITE VIDEO

- HOT BLACKBODY TEMPERATURE (3)
- COLD BLACKBODY TEMPERATURE (3)
- TELESCOPE TEMPERATURE (1)
- RELAY OPTICS TEMPERATURE (1)
- CHOPPER TEMPERATURE (1)

ANALOG

- HOT BLACKBODY TEMPERATURE (5)
- COLD BLACKBODY TEMPERATURE (5)
- TELESCOPE TEMPERATURE (1)
- CHOPPER TEMPERATURE (1)
- RELAY OPTICS TEMPERATURE (1)
- HCT DETECTOR TEMPERATURE (2)

3.4.2 Scan and Chopper Motors

Table 3–13 is a summary of motor parameters for the scanner and chopper.

Figure 3–31 shows a block diagram of the motor control servo system for the scanning mirror assembly. The design employs a brushless dc motor controlled by a phase-locked loop (PLL). Past studies (and recommendations of NASA specialists) have shown that the use of a brushless dc motor is preferable especially when a synchronous gearless scanning system is required to meet tight short-term scan stability when operating in an adverse environment. An encoder provides the phase timing. The motor electronics logic contains a frequency reference, countdown logic, and a phase detector for the PPL. The encoder provides commutation signals for the master drive amplifier. The spin motor analog control converts the phase detector logic signals to an analog voltage and provides the frequency compensation for the PPL.

The encoder has five tracks: an incremental phase sensing track for the PLL, two tracks to provide commutation signals for the motor and two remaining tracks to synchronize the operation of the instrument data format.

A line to line stability of 25 μs has been achieved in the CTS design.

3.4.3 Power Switching and Operational Modes

A power switching diagram showing distribution of power from aircraft power is given in Figure 3–32. All power distribution is done within the electronics box.

There are three operational modes of the CTS system:

1. Test
2. Flight
3. Descent

In the test mode all functions of the scanner are operational except that the calibration sources are not activated.

Table 3-13 CTS MOTOR INFORMATION

SCAN MOTOR

• TYPE	BRUSHLESS DC MOTOR
• COMMUTATION METHOD	HALL SENSORS
• OPERATING SPEED	2 REV/s
• TORQUE SENSITIVITY	6.4 oz-in./amp
• BACK EMF	45 mV/rad/s

CHOPPER MOTOR

• TYPE	INDUCTION MOTOR
• NO. OF POLES	4
• FULL LOAD SPEED	9200 REV/min
• FULL LOAD TORQUE	5 oz-in.
• EXCITATION VOLTAGE	115 V_{rms}
• EXCITATION FREQUENCY	340 Hz

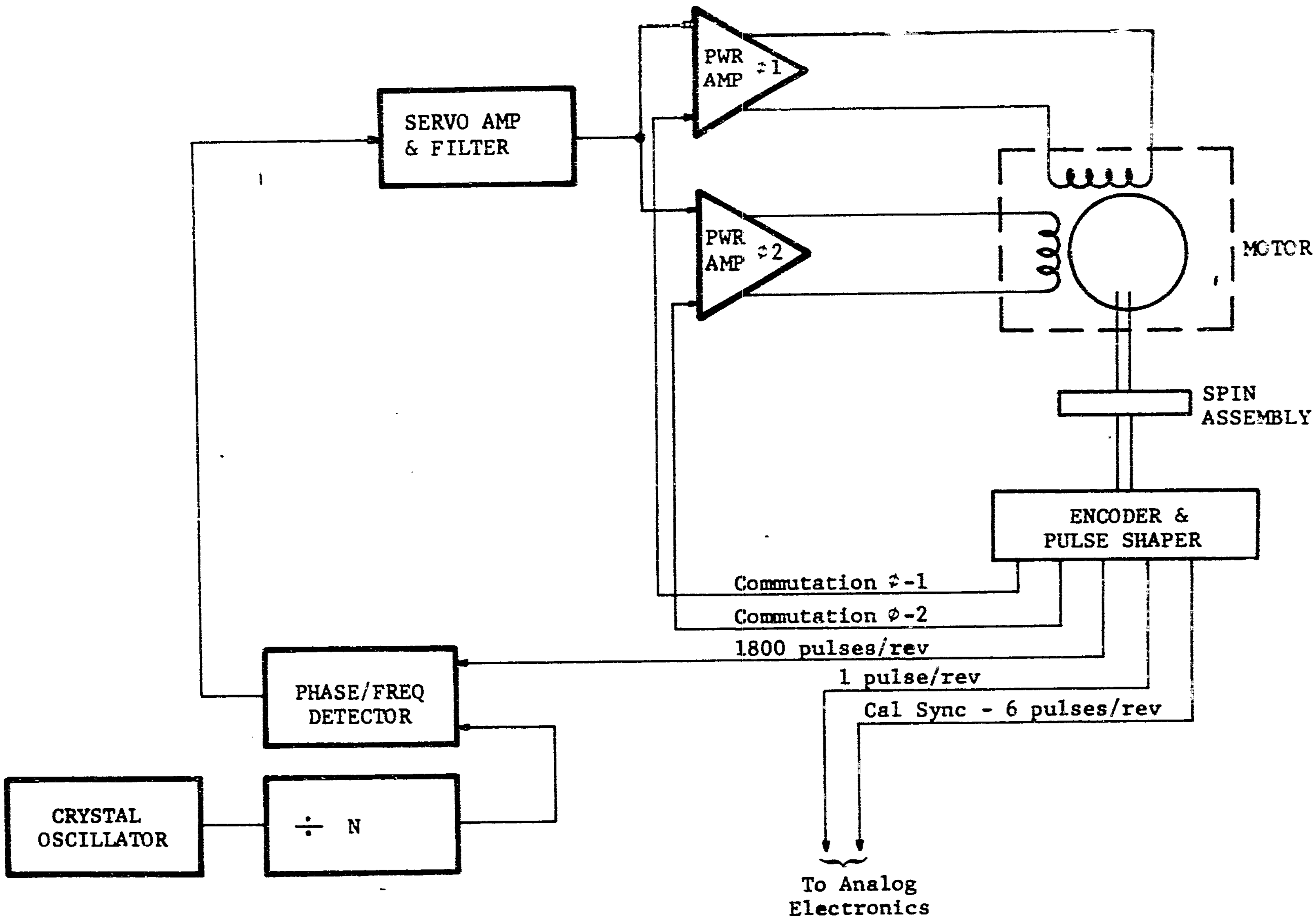


Figure 3-31 Block Diagram of Spin Motor Control

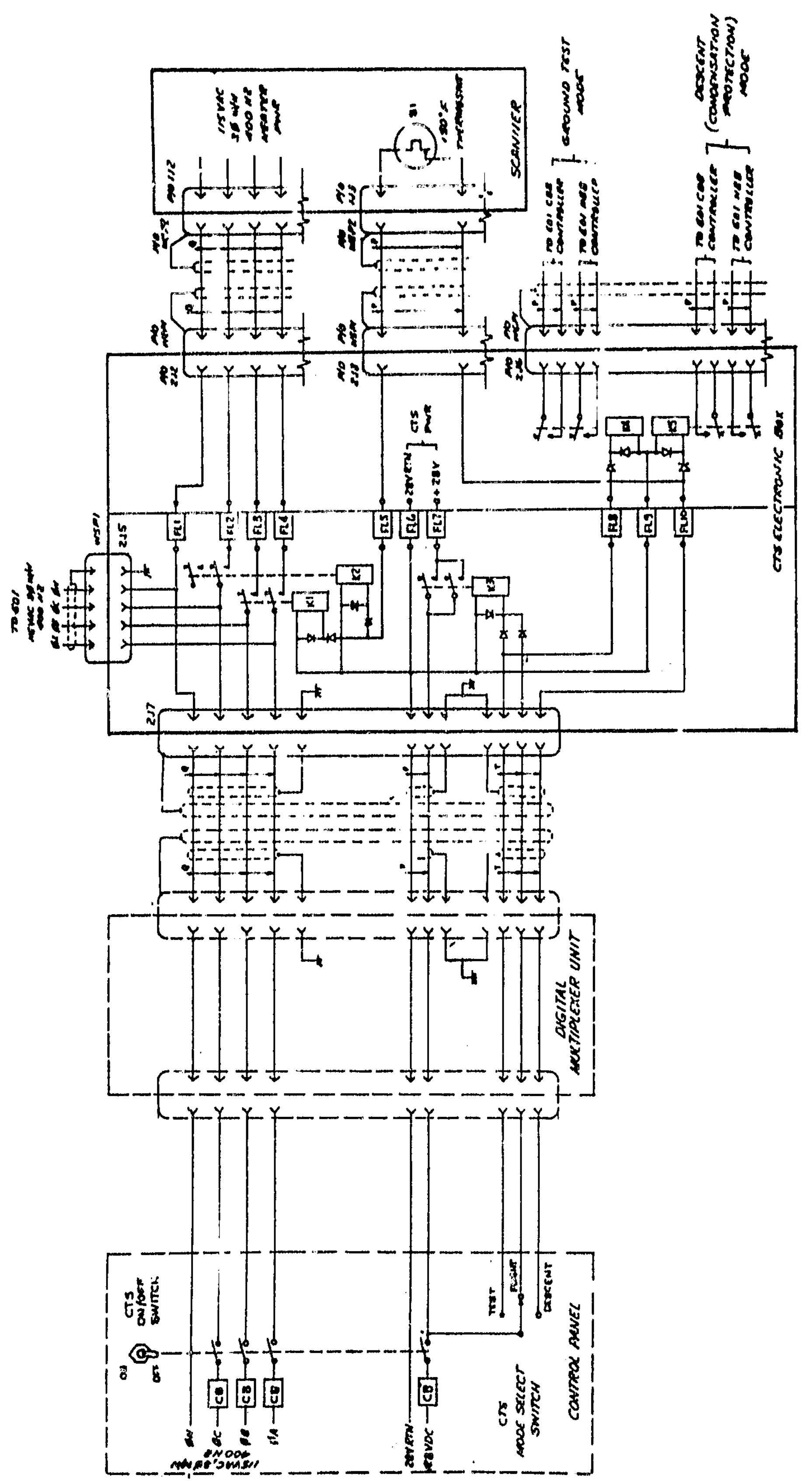


Figure 3-32 Power Switching

The flight mode is the full operational configuration of the system, while in the descent mode, all system functions are off except for the heating blankets. During descent, the heating blankets are switched on for condensation protection. Power status of the three modes is given in Table 3-14.

3.4.4 Schematics

The final circuits configuration can be found in up to date schematics delivered separately and listed in Appendix C.

Table 3-14 CTS MODE POWER STATUS

MODE	POWER STATUS		
	CTS 28V POWER	CTS 115V POWER	EOI 115V POWER
TEST	ON	OFF	OFF
FLIGHT	ON	OFF	ON
DESCENT	OFF	ON	ON

SECTION 4
SYSTEM TESTS

This section gives results of tests performed at various levels of assembly.

All test results are given either in tabular or graphical formats.

4.1 IN-PROCESS TESTS

Results of tests performed on piece parts or sub-assemblies prior to system integration are given in this section.

4.1.1 Scanner Shaft and Bearings

a) Total Indicated Runout $\leq 150 \times 10^{-6}$ inches
b) Bearing Torque Variation (Rough Spots) = 3.7 oz - inches

4.1.2 Chopper Jitter

a) Jitter = $\pm 0.5\,\mu s$ per revolution
b) Demodulation error (ϕ_e) due to jitter:

$$\phi_e = \pm 0.025\%$$

4.1.3 Telescope Image Quality

See Figures 4-1 through 4-7. These traces were taken with a scanning slit microscope at various stages of system assembly.

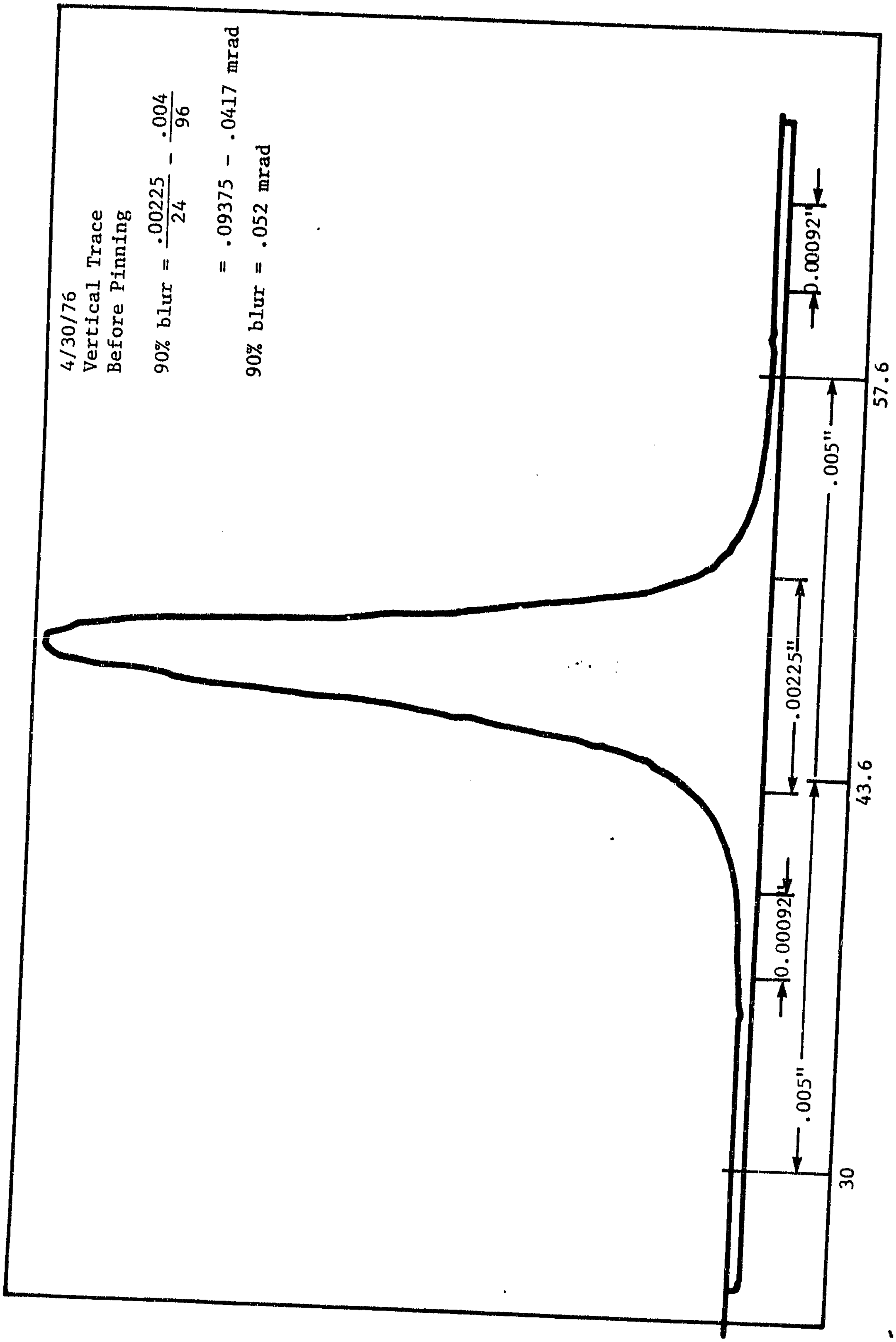

4/30/76
Vertical Trace
Before Pinning
90% blur = $\frac{.00225}{24} - \frac{.004}{96}$
= .09375 - .0417 mrad
90% blur = .052 mrad
0.00092"
.005"
.00225"
0.00092"
.005"
57.6
43.6
30

Figure 4-1

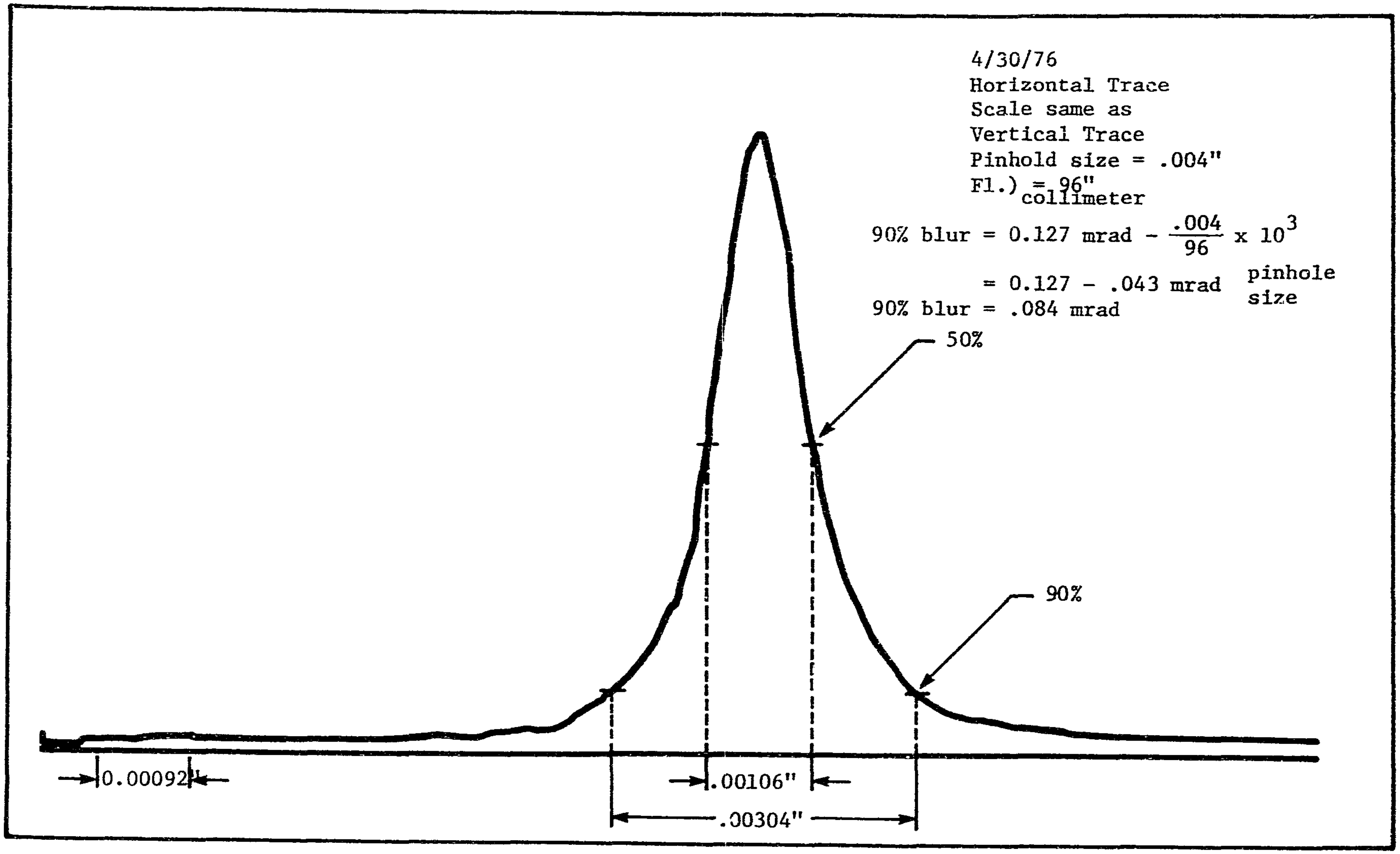

4/30/76
Horizontal Trace
Scale same as
Vertical Trace
Pinhold size = .004"
Fl.)collimeter = 96"
90% blur = 0.127 mrad - .004/96 x 10^3
= 0.127 - .043 mrad pinhole size
90% blur = .084 mrad
50%
90%
0.00092
.00106"
.00304"

Figure 4-2

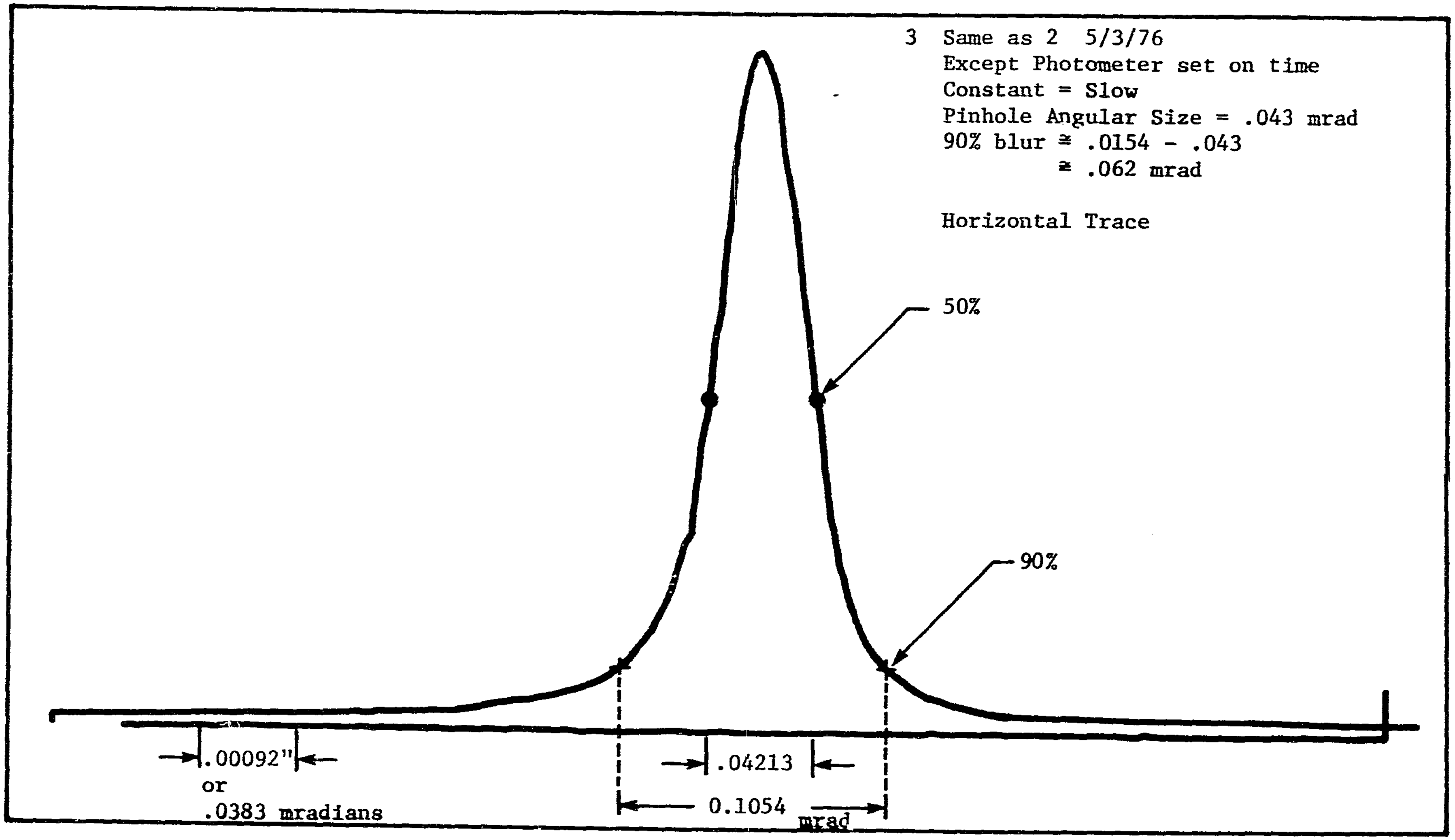
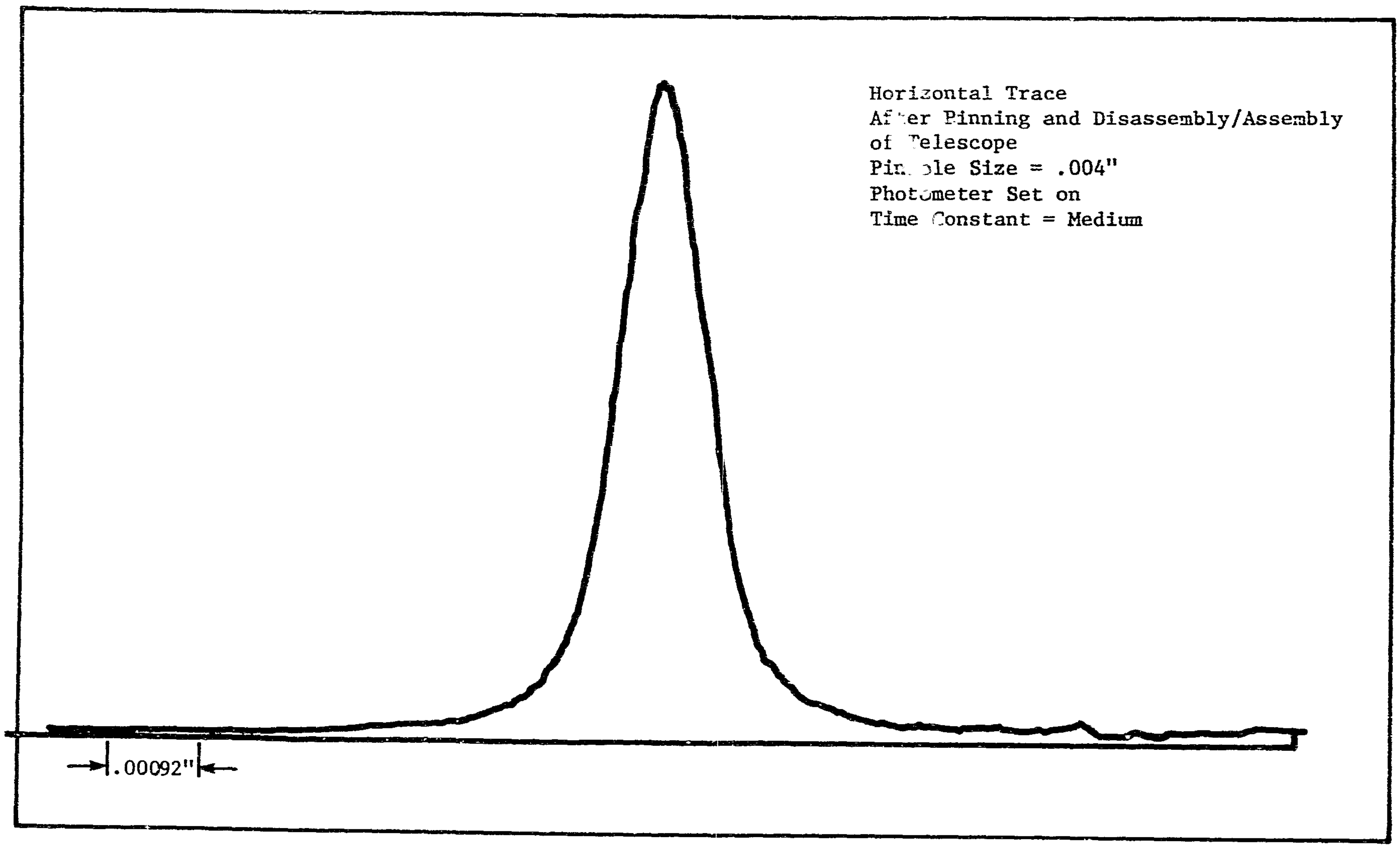

3 Same as 2 5/3/76
Except Photometer set on time
Constant = Slow
Pinhole Angular Size = .043 mrad
90% blur ≅ .0154 - .043
≅ .062 mrad
Horizontal Trace
50%
90%
.00092"
or
.0383 mradians
.04213
0.1054
mrad

Figure 4-3



Horizontal Trace
After Pinning and Disassembly/Assembly
of Telescope
Pinhole Size = .004"
Photometer Set on
Time Constant = Medium
.00092"

Figure 4-4

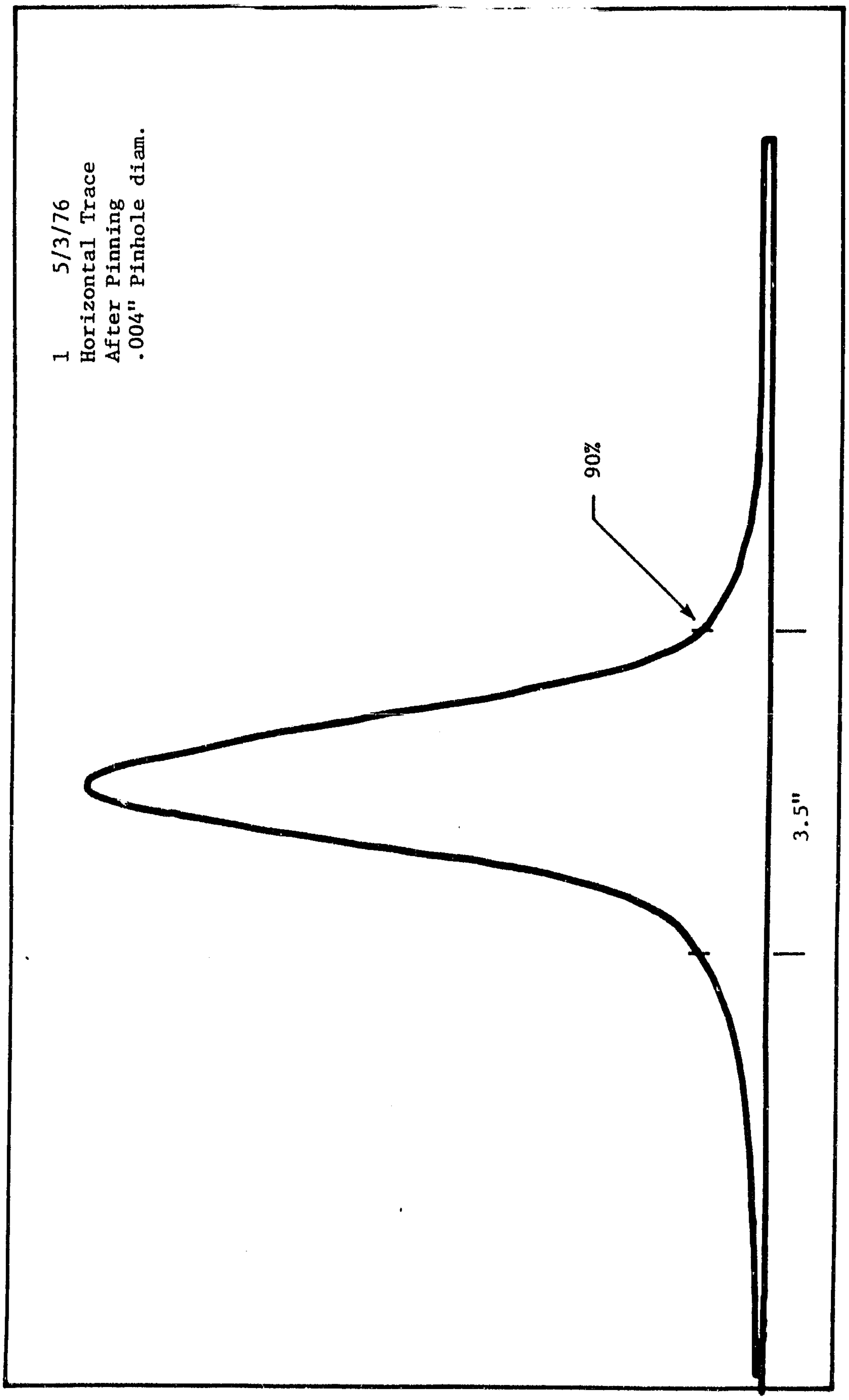

1 5/3/76
Horizontal Trace
After Pinning
.004" Pinhole diam.
90%
3.5"

Figure 4-5

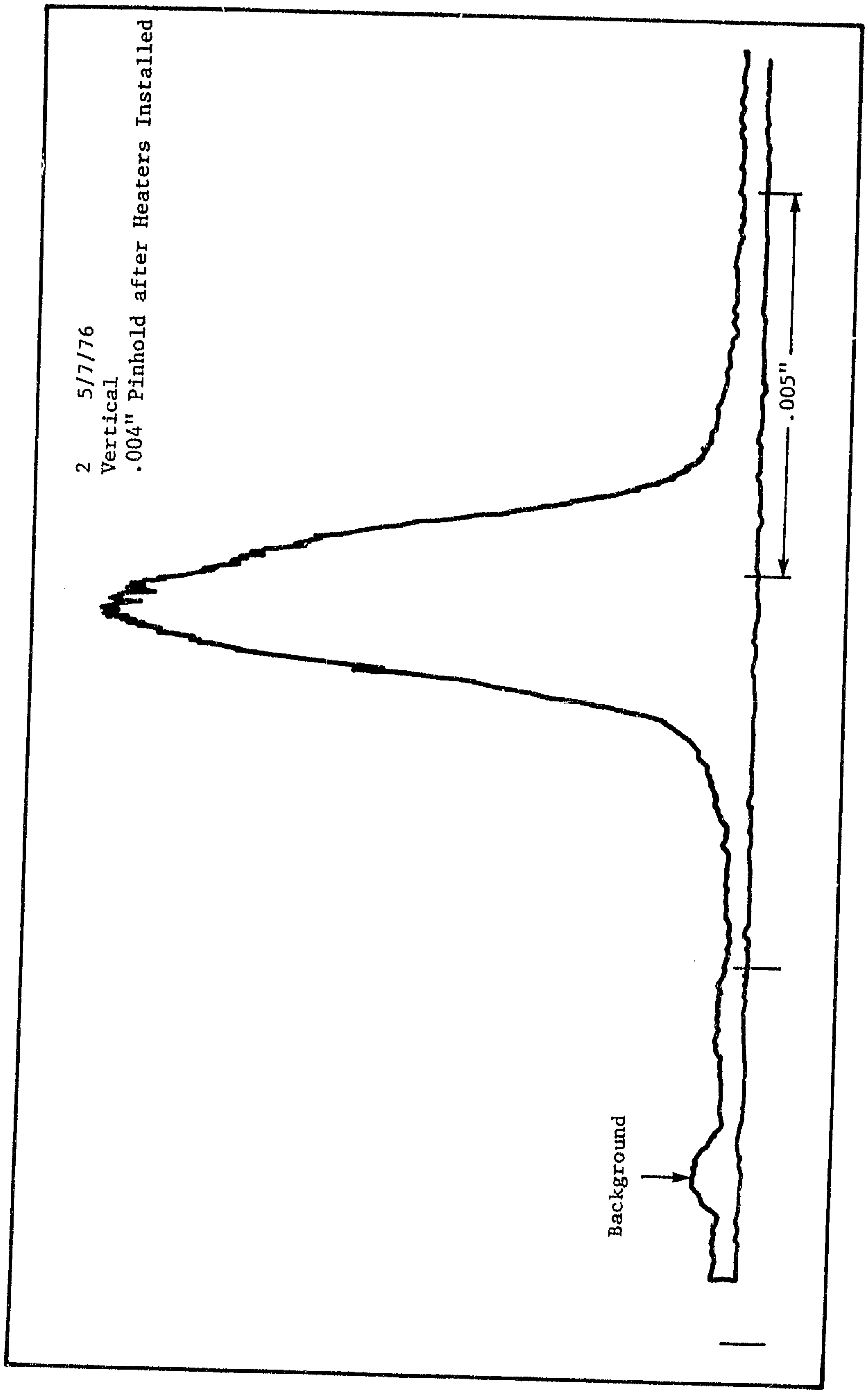

2 5/7/76
Vertical
.004" Pinhold after Heaters Installed
.005"
Background

Figure 4-6

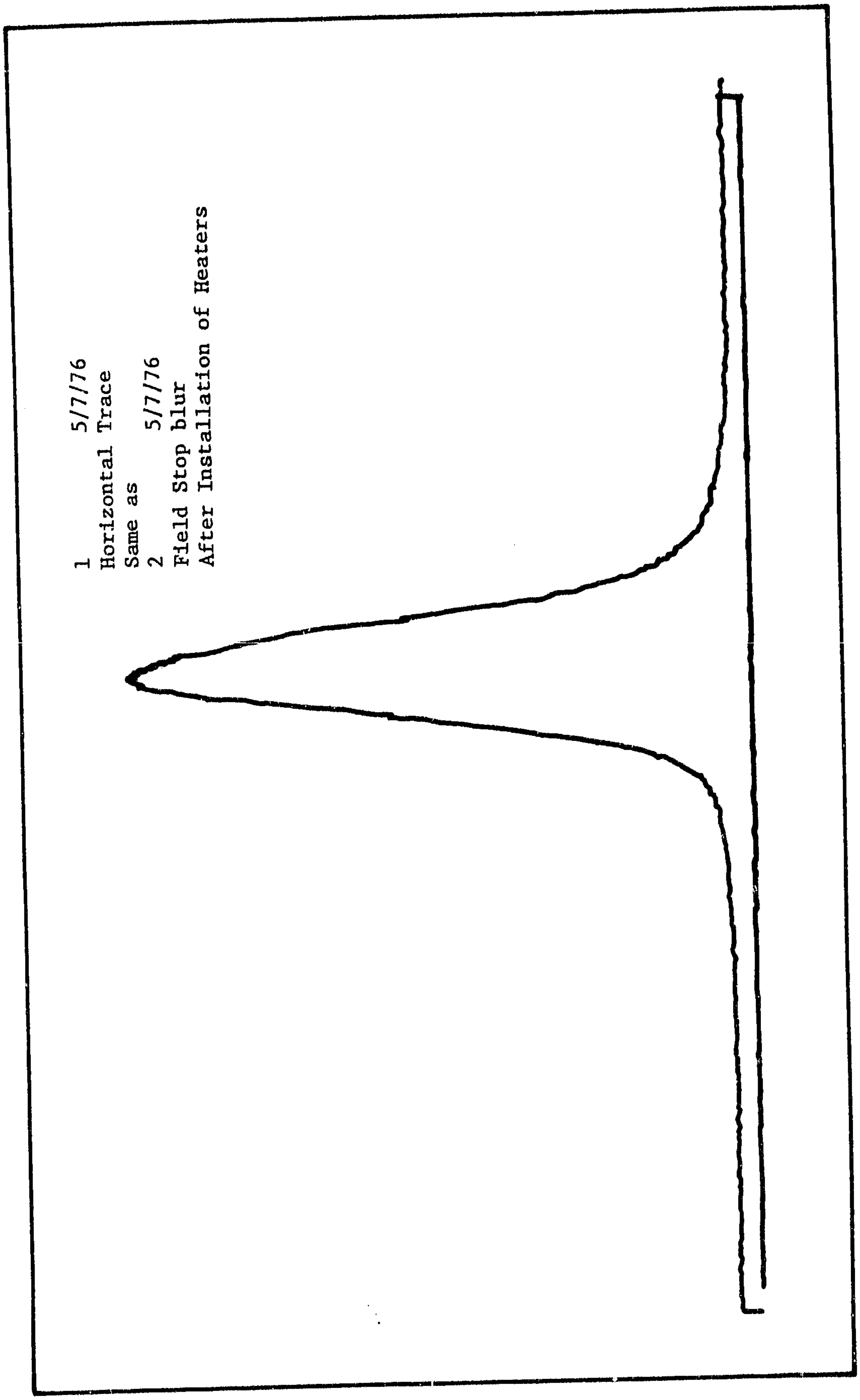

1 5/7/76
Horizontal Trace
Same as
2 5/7/76
Field Stop blur
After Installation of Heaters

Figure 4-7

4.1.4 Detector Spatial Response

Figures 4-8 and 4-9 are plots of channel 2 detector spatial response. This data was taken by measuring the signal from a pinhole/chopper combination lcoated at the focal plane of a collimating mirror.

4.1.5 Spectral Response

Figures 4-10 through 4-12 are relative transmittance curves for each of the three spectral filters. Figures 4-13 and 4-14 are relative spectral response curves for the two HCT detectors.

4.1.6 Scan Speed Stability

Line to line jitter due to scan motor and drive electronics instabilities and bearing rough spots was measured. The maximum allowable jitter is 50µs. The measured jitter is less than 25µs.

4.2 VIBRATION TESTS

Vibration testing was performed at the Acton Environmental Testing Corporation. A complete test report is included in Appendix D. Prior to testing of the CTS units, a vibration survey was performed on the test fixture alone to determine its resonant frequencies. Vibration levels at these frequencies were then attenuated by the proper factors during CTS system tests.

Channel 2 I.F.O.V. Plot
X Axis

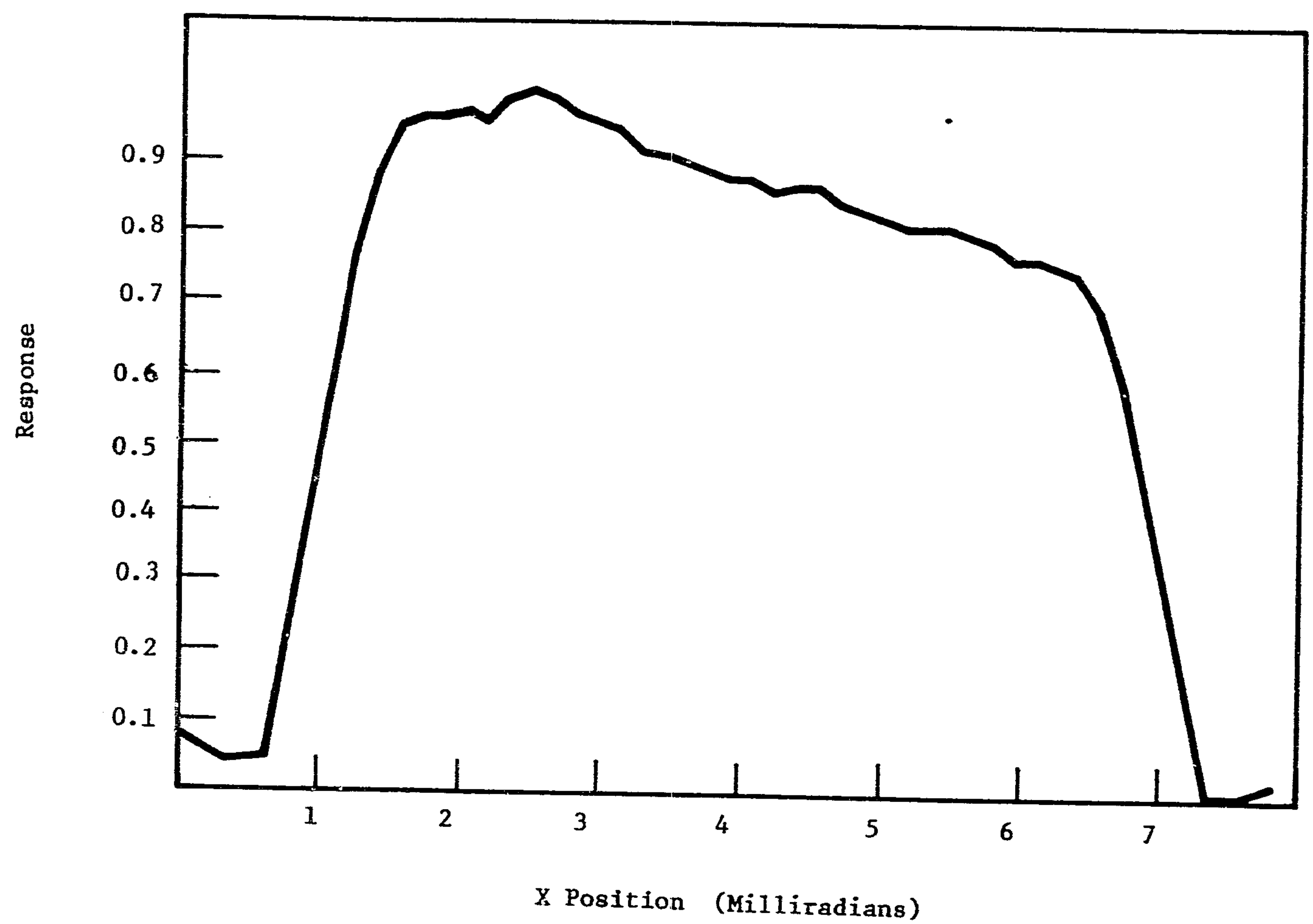


Figure 4-8

Channel 1 2 I.F.O.V Plot
Y Axis

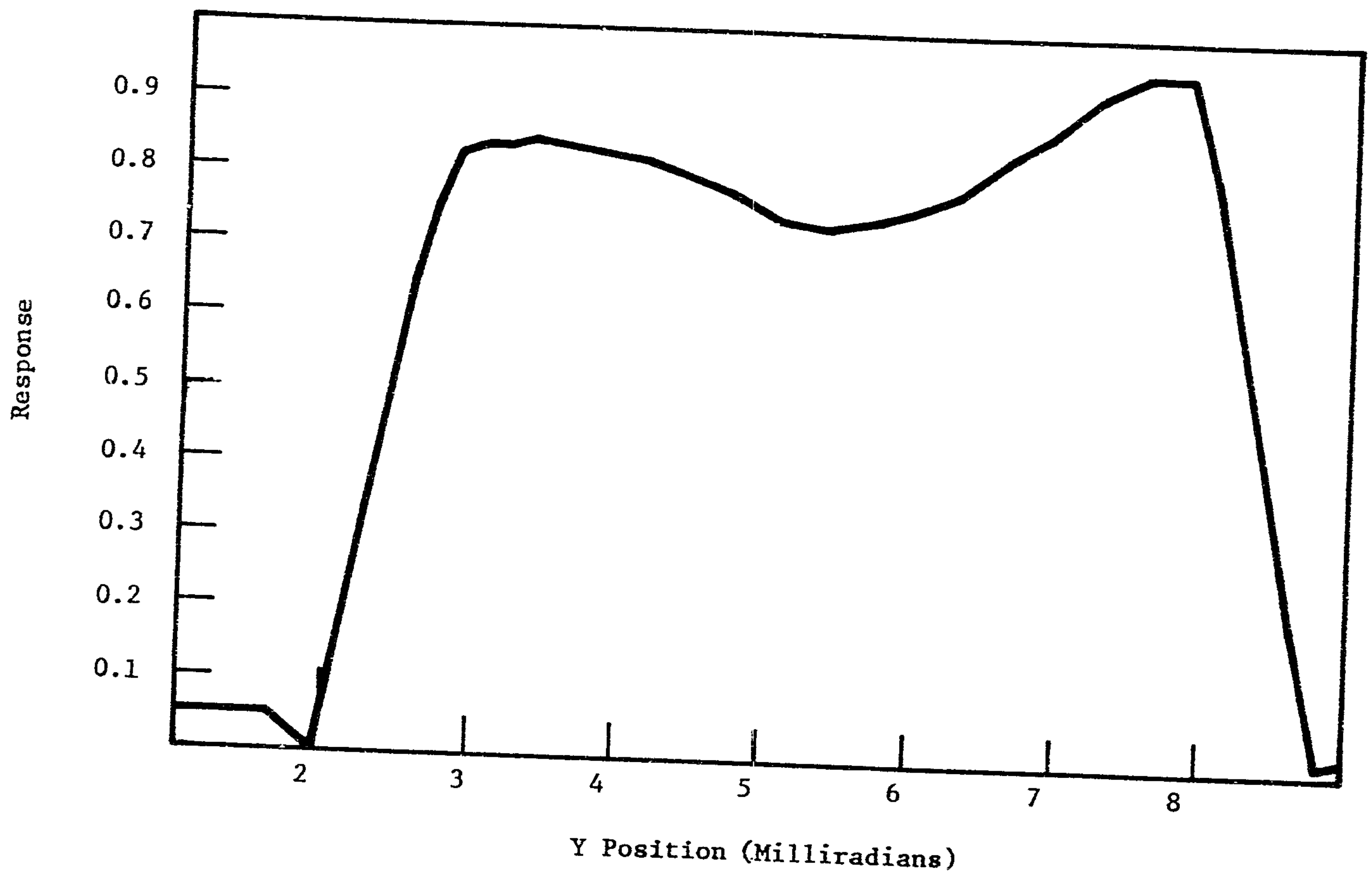


Figure 4-9

Channel 1 Filter Relative
Spectral Transmittance
Max. Response = .972

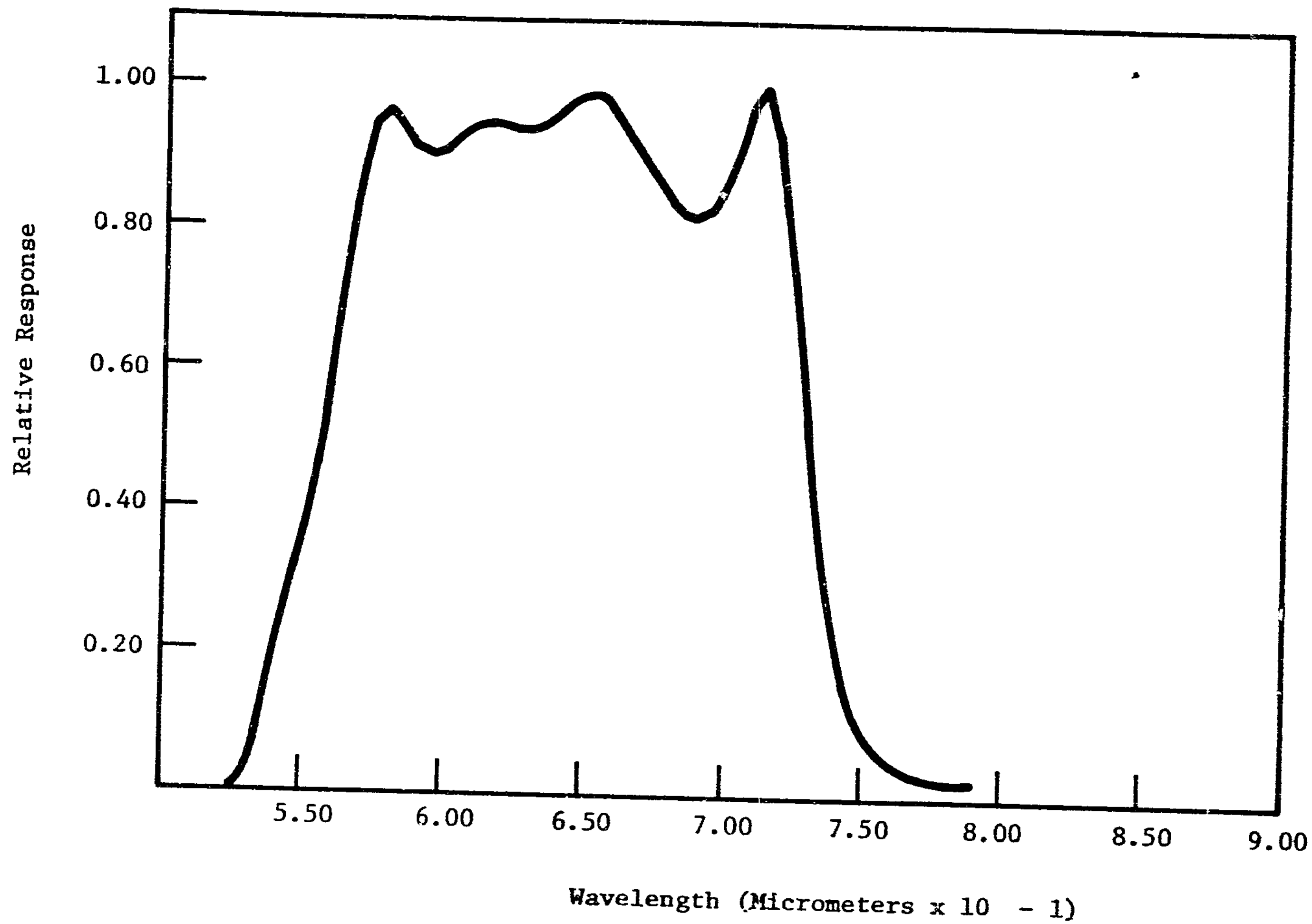


Figure 4-10

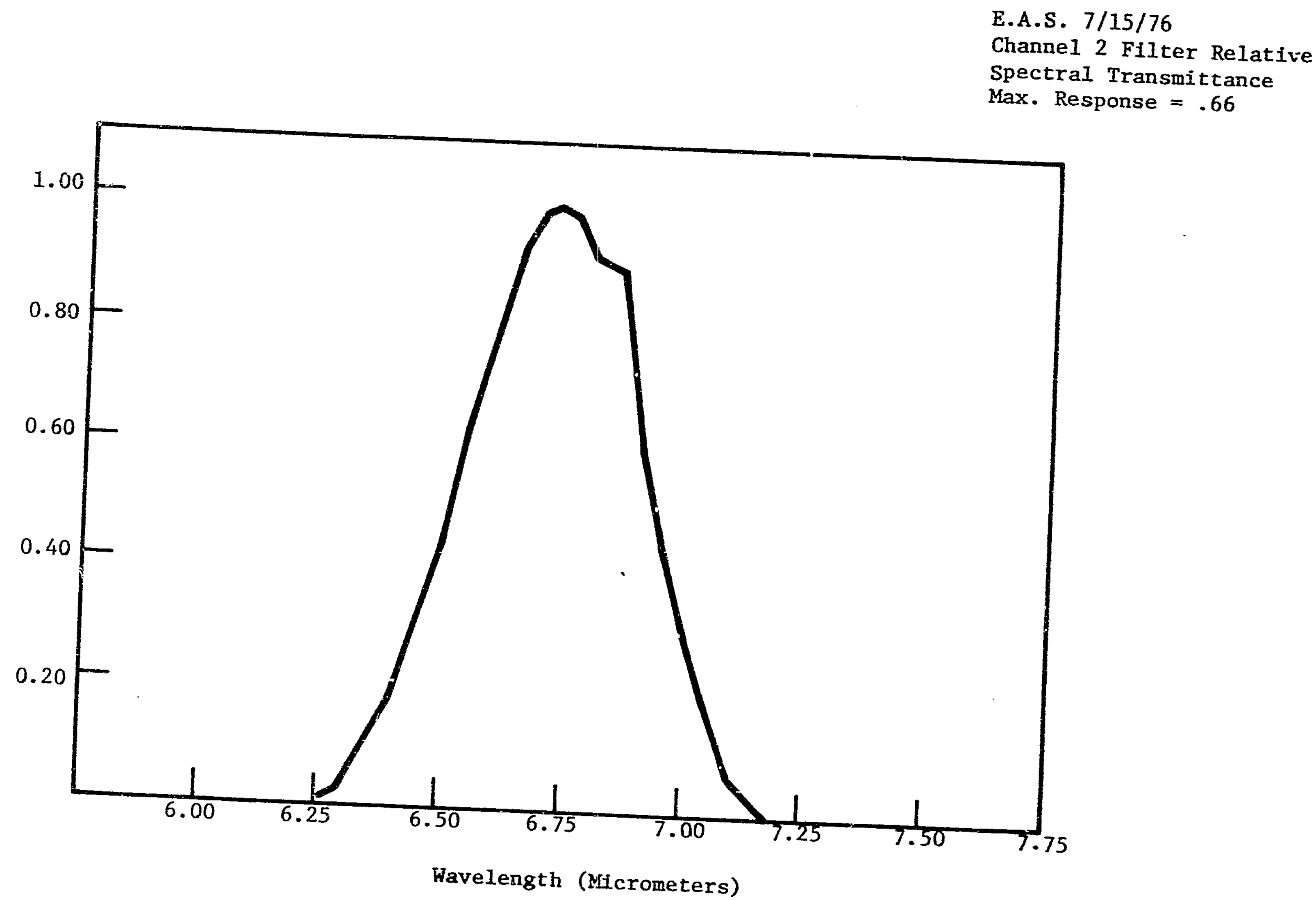

E.A.S. 7/15/76
Channel 2 Filter Relative
Spectral Transmittance
Max. Response = .66
1.00
0.80
0.60
0.40
0.20
Relative Response
6.00
6.25
6.50
6.75
7.00
7.25
7.50
7.75
Wavelength (Micrometers)

Figure 4-11

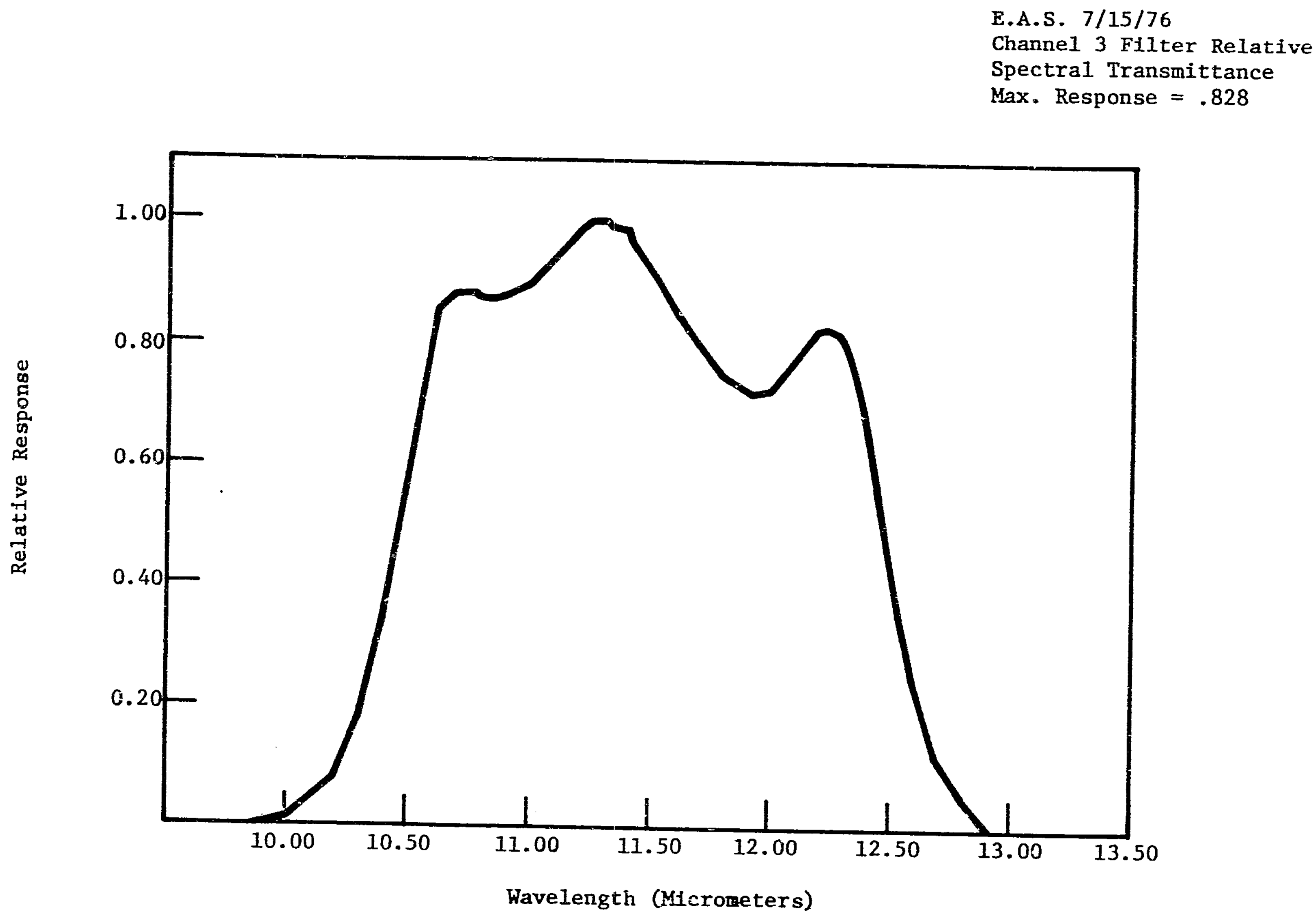


Figure 4-12

7804-5

E.A.S. 7/22/76

Channel 2 Detector
Relative
Spectral Response
D-Star Max. = 3.38 E 10

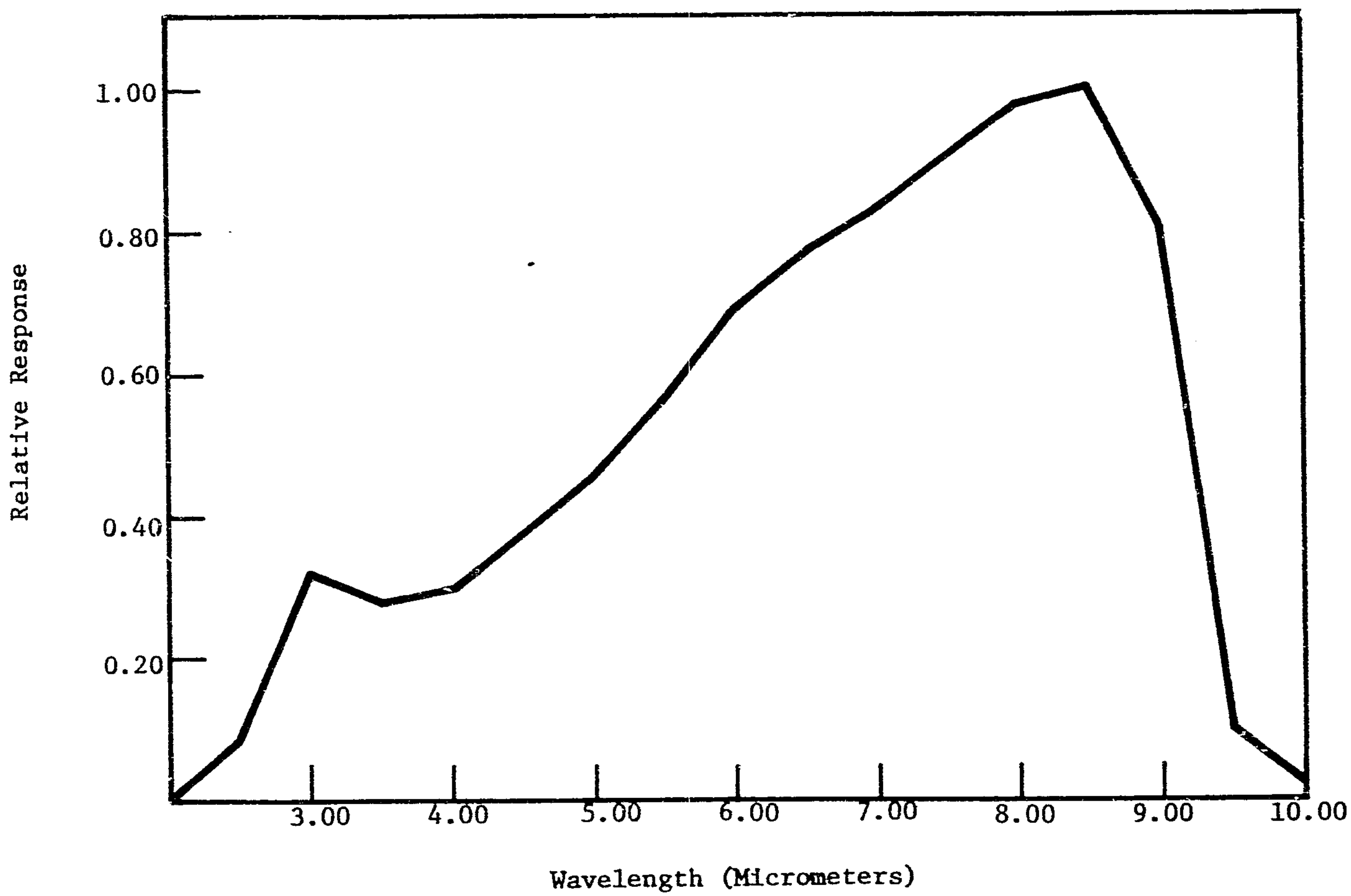


Figure 4-13 .

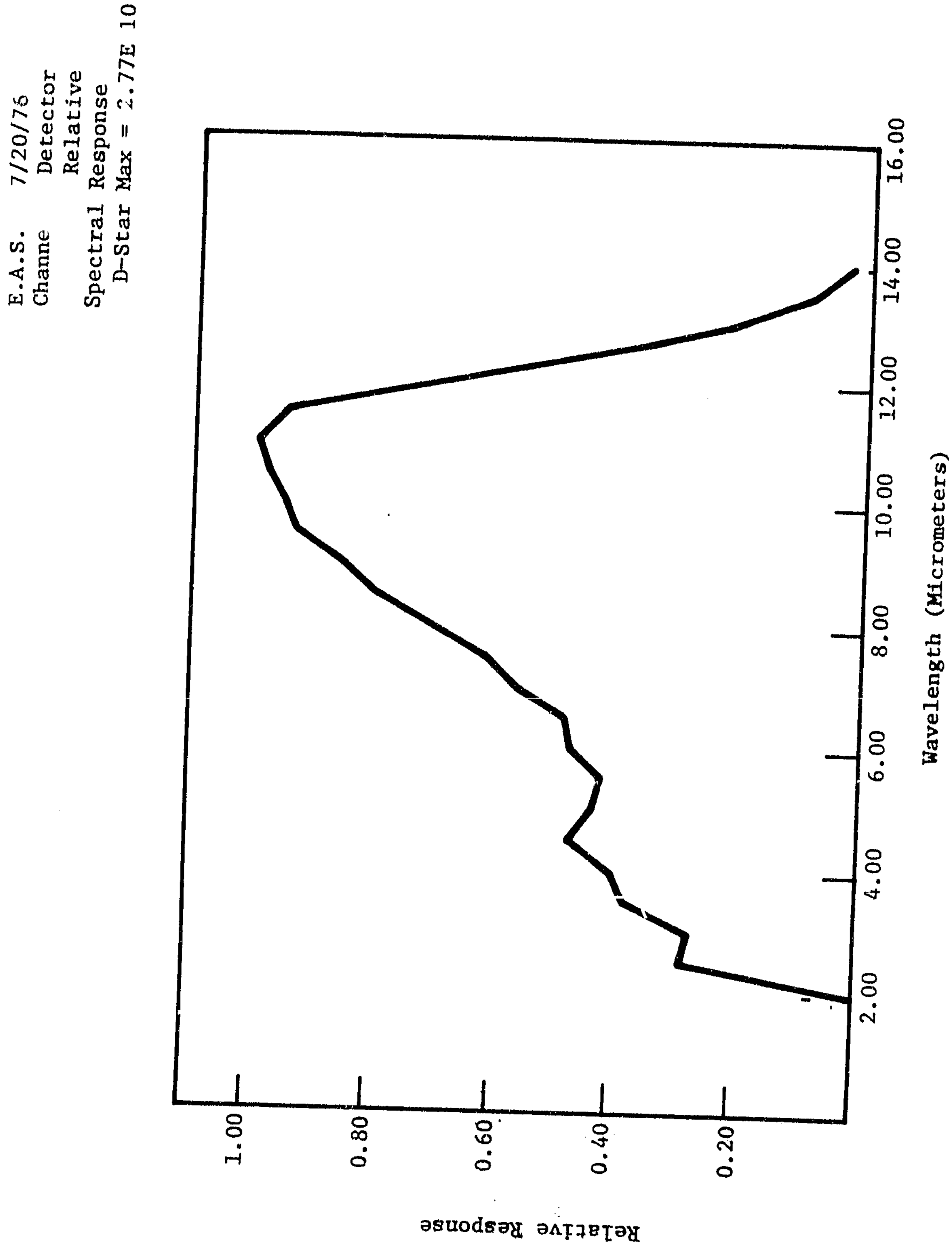

E.A.S. 7/20/76
Channe Detector
Relative
Spectral Response
D-Star Max = 2.77E 10
Relative Response
1.00
0.80
0.60
0.40
0.20
2.00
4.00
6.00
8.00
10.00
12.00
14.00
16.00
Wavelength (Micrometers)

Figure 4-14

APPENDIX A

COOLER INSTRUCTION SHEETS

INSTRUCTION SHEET

MODEL 916AS COOLER

Electro Optical Industries, Inc.
P.O. Box 3770, Santa Barbara,
California, 93105
Phone: (805)964-6701

MODEL 916AS OPERATION

PROCEDURE

The model 916AS is a special recirculating cooler manufactured by Electro Optical Industries, Inc. It is designed for airborne use, and is powered from 115 VAC, 400Hz. No periodic maintenance is required. If a failure occurs, drawings useful for repair information are supplied.

The model 916AS is a recirculating heat exchanger useful in water cooling a remote heat source. Heat is removed with a recirculating fluid. The fluid is cooled in turn by passing through a small radiator. A small fan is included in the assembly to maintain air circulation through the radiator fins.

Do this to fill and operate:

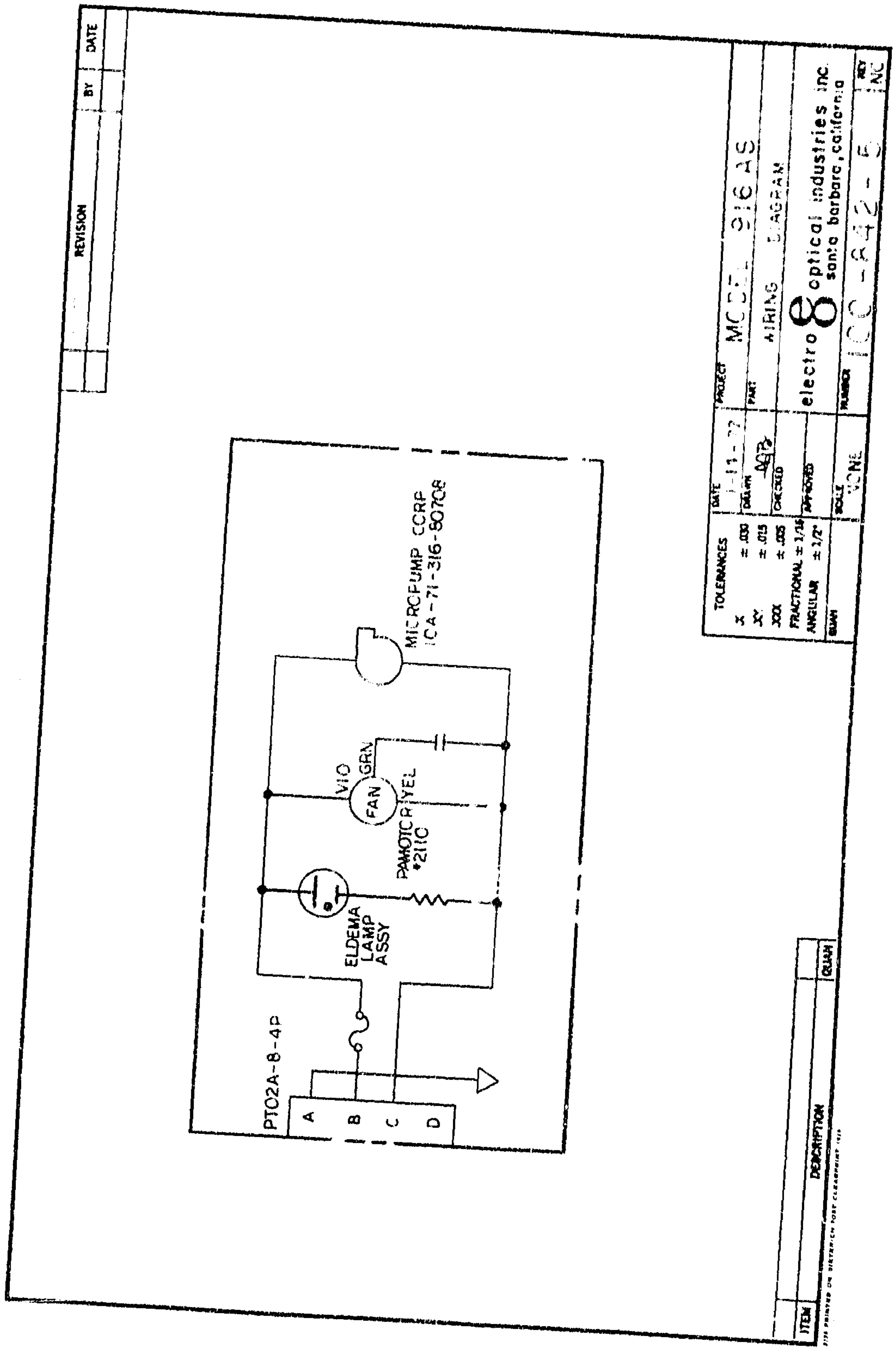
1. Open hinged lid on cooler by removing screws.
2. Remove radiator tank cap and fill with water.
3. To turn on cooler - set switch to "on" position.
4. Observe water flow through plastic tubing.
5. If water does not flow through system - tip cooler towards pump side for priming.
6. Replace radiator cap and close lid cover.

(1)

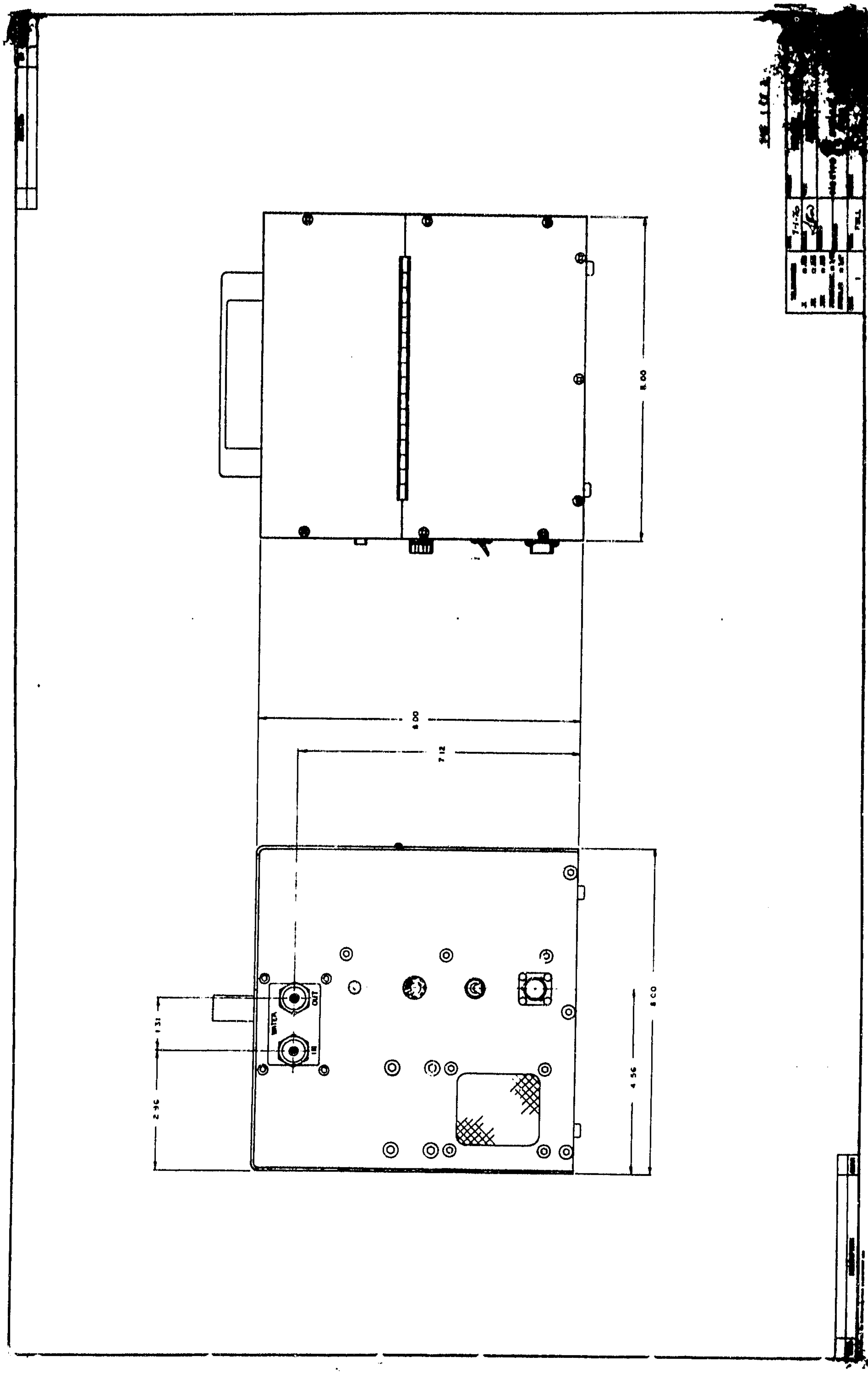
LIST OF DRAWINGS:

100-842-5 NC	Wiring Diagram
100-842 NC	Assembly (sheet 1 of 2)
100-842 NC	Assembly (sheet 2 of 2)

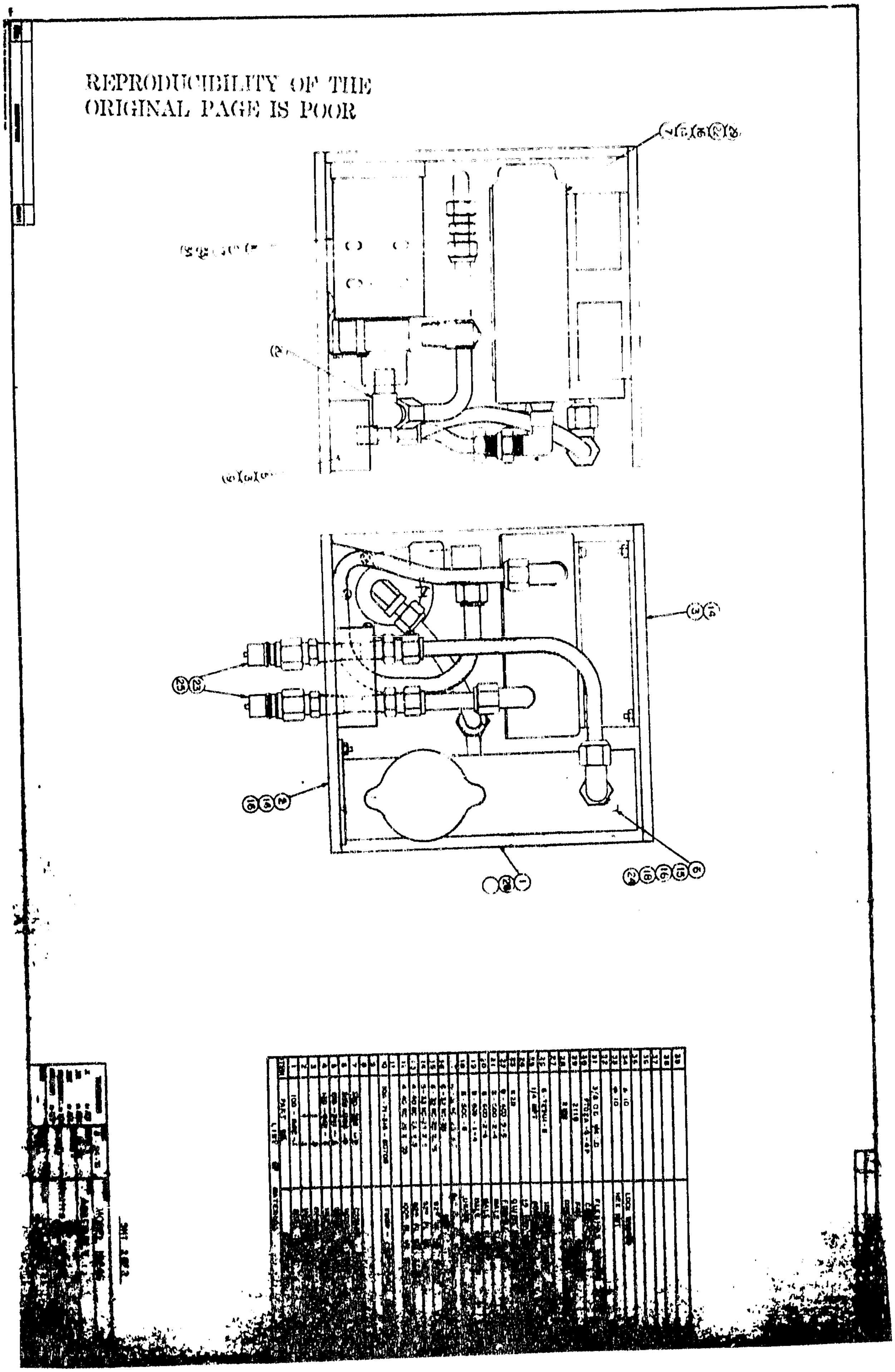
(2)



REPRODUCIBILITY OF THE
ORIGINAL PAGE IS POOR

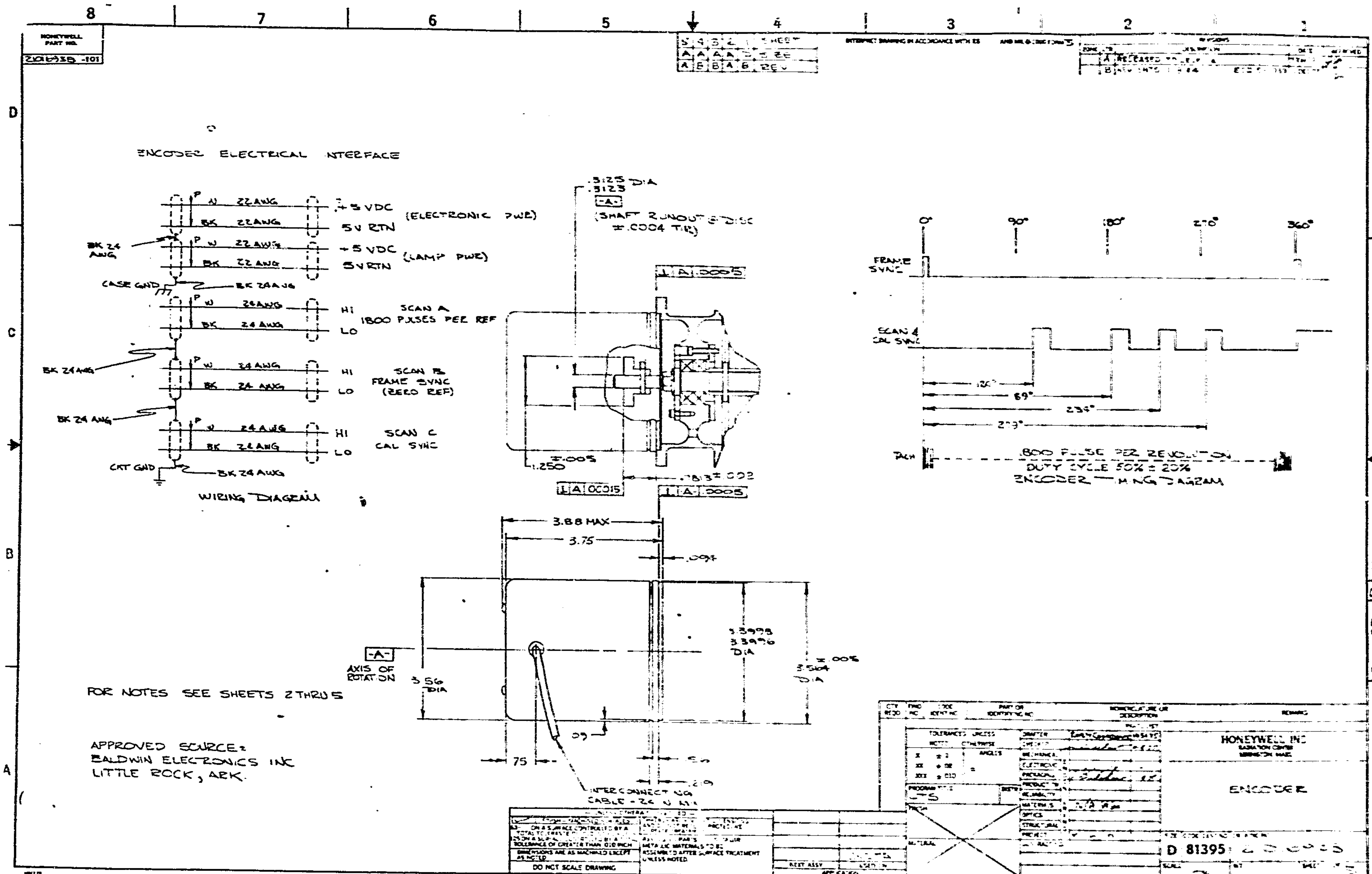

8.00
7.12
8.00
1.31
2.96
4.56
WATER
IN
OUT

REPRODUCIBILITY OF THE
ORIGINAL PAGE IS POOR



APPENDIX B

ENCODER SPECIFICATION


HONEYWELL PART NO.
ENCODER ELECTRICAL INTERFACE
+5 VDC (ELECTRONIC PWR)
5V RTN
+5 VDC (LAMP PWR)
5V RTN
CASE GND
SCAN A 1800 PULSES PER REF
SCAN B FRAME SYNC (ZERO REF)
SCAN C CAL SYNC
CKT GND
WIRING DIAGRAM
BK 24 AWG
22 AWG
24 AWG
HI
LO
.3125 .3123 DIA
-A-
(SHAFT RUNOUT @ DISC ±.0004 TIR)
FRAME SYNC
SCAN 4 CAL SYNC
TACH
800 PULSE PER REVOLUTION
DUTY CYCLE 50% ± 20%
ENCODER TIMING DIAGRAM
3.88 MAX
3.75
AXIS OF ROTATION
3.56 DIA
3.3998 3.3996 DIA
3.564 ±.005 DIA
INTERCONNECTING CABLE
FOR NOTES SEE SHEETS 2 THRU 5
APPROVED SOURCE:
BALDWIN ELECTRONICS INC
LITTLE ROCK, ARK.
HONEYWELL INC
ENCODER
D 81395
DO NOT SCALE DRAWING

C-2

REVISIONS			
LTR	DESCRIPTION	DATE	APPROVED
A	RELEASED TO LEVEL A	7Nov75	

1.0 SCOPE

This drawing describes the requirements and functions of an Optical Shaft Encoder used in conjunction with the Scan Mirror Assembly of the Cloud Top Scanner. The primary function of the encoder is to provide frame synchronization corresponding to the start of the scan period, calibration source synchronization and an incremental tachometer output.

2.0 TECHNICAL REQUIREMENTS

2.1 <u>Function</u>

The function of the encoder is to provide the following outputs:

a) A once per revolution frame synchronization pulse is required corresponding to the start of the data taking scan period.

b) Active scan and calibration source synchronization pulses are required to identify the location of the active scan period and each of three calibration sources.

c) A tachometer output is required to provide verification of scan wheel rotational rate.

The position at which each of the output pulses occurs is given in the "Encoder Timing Diagram" shown on sheet 1.

SIZE	CODE IDENT NO.	
A	81395	21016938
SCALE	WT	SHEET 2 OF 5

REVISIONS			
LTR	DESCRIPTION	DATE	APPROVED
A	RELEASED TO LEVEL A	7 Nov 75	

2.2 Mechanical Characteristics

2.2.1 Physical Configuration - The encoder shall consist of a Housing Assembly containing the Code Disc Readout Assembly and associated electronics and a code disc. The code disc shall be attached to an HRC furnished disc mounting flange. The Encoder Housing shall be as specified on Sheet 1.

2.2.2 Weight - The weight of the encoder shall not exceed TBD ounces.

2.3 Electrical Characteristics

2.3.1 The power required for the lamps and encoder electronics shall not exceed the following:

Lamps +5VDC ± 5% $<$ TBD watts

Electronics +5VDC ± 5% $<$ TBD watts

2.3.2 Electrical Interface

2.3.2.1 Isolation - All signal and power leads shall be isolated from the encoder housing. The lamp power shall be isolated from the electronic power.

REVISIONS			
LTR	DESCRIPTION	DATE	APPROVED
	EASED TO LEVEL A	7 Nov 75	

2.3.… …ctions: All connections shall be brought …s specified in wiring diagram, Sheet 1. … color and size to be as noted. Wire to … er MIL-W-16873/4 Type E. Tag wire ends an… mark functions (i.e., "SCAN A", "SCAN B" etc.) Lead length outside case to be 24.0 inches min.

2.3.3 Output Characteristics - Each output waveform shall exhibit the following pulse characteristics under the following conditions:

a) Operating temperature per 2.3.4
b) Total shaft runout TBD
c) Random variation in shaft runout TBD
d) Axial motion of shaft TBD
e) Operating speed 120 RPM unidirectional

Items (b) through (e) above relate to interface conditions associated with direct mounting to HRC structure and shaft as shown on Sheet 1.

2.3.3.1 Amplitude - All outputs differential via transmitter line driver. Pulse present will follow positive true convention.

Voltage Level (pos)	$>$ 2.4 VDC
Voltage Level (neg)	$<$ 0.7 VDC
Leading Edge	$<$ 400 ns
Trailing Edge	$<$ 400 ns
Pulse Width	See Figure 1

REVISIONS			
LTR	DESCRIPTION	DATE	APPROVED
A	RELEASED TO LEVEL A	7 Nov 75	

2.3.3.2 Accuracy - Absolute position accuracy of all pulse transistions <30 sec.

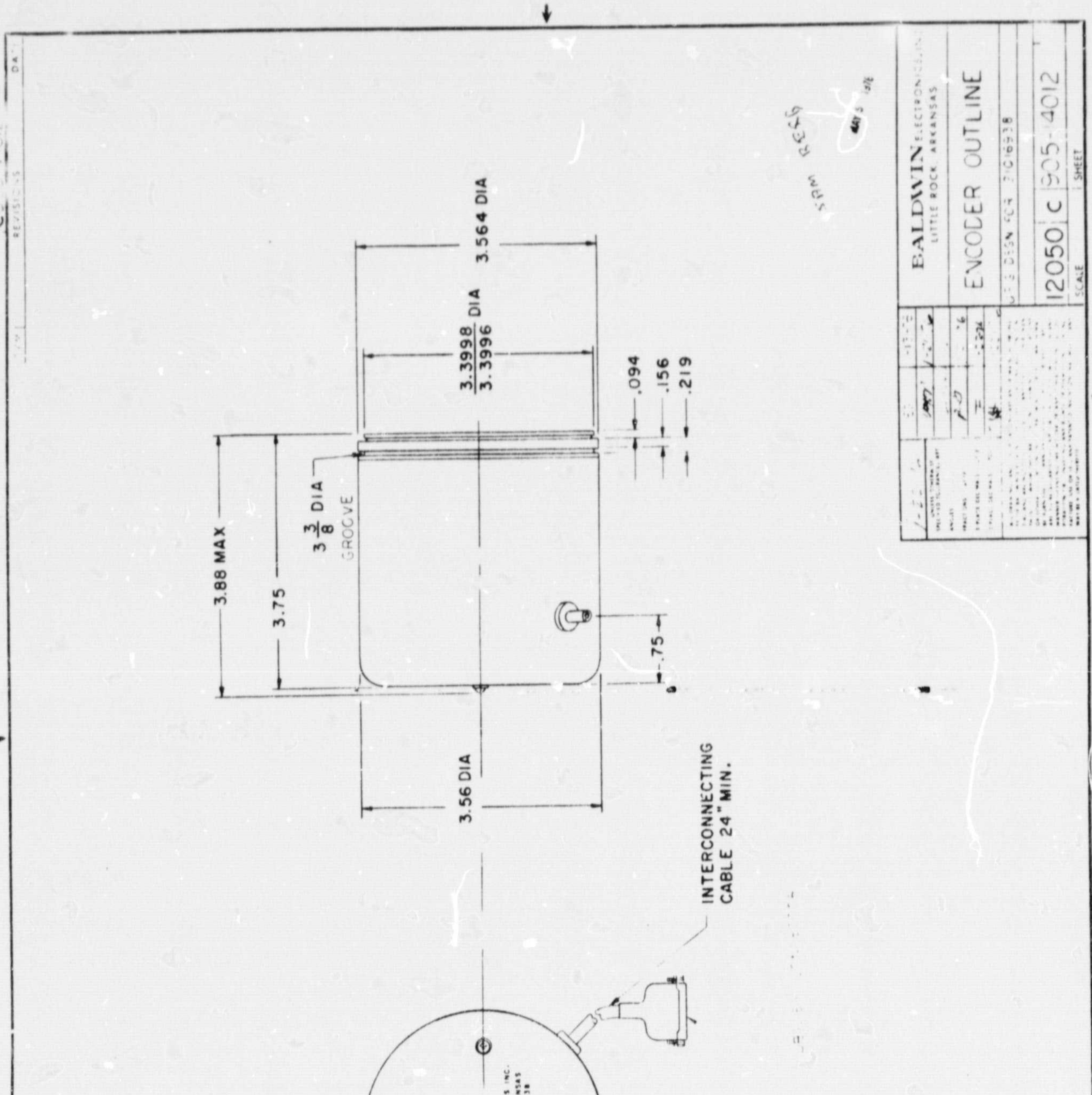
2.3.4 Environment:

Operating Temperature Range -40°C to +40°C
Non-Operationg Temperature Range -40°C to +40°C

Altitude-Operating - Sea Level to 70,000 Ft.

Vibration-Operating - 1G at 20 to 2,000 Hz

SIZE	CODE IDENT NO.	
A	81395	21016938
SCALE	WT	SHEET 5 OF 5


BALDWIN ELECTRONICS INC.
LITTLE ROCK, ARKANSAS
ENCODER OUTLINE
12050 C 905-4012
3.564 DIA
3.3998
3.3996 DIA
.094
.156
.219
3 3/8 DIA
GROOVE
3.88 MAX
3.75
.75
3.56 DIA
INTERCONNECTING
CABLE 24" MIN.

APPENDIX C

DRAWING LIST

CTS DWG + PARTS LIST

ITEM	ASSY LEVEL 1	2	3	4	5	6	7	DWG. NO.	SIZE	REF. DESIG.	TITLE
1								YK45A1			INSTALLATION DWG CTS SYSTEM
2								UK45A1			INSTALLATION DWG CTS TEST EQUIP
3								21012855	D		SCHEMATIC, PWR INPUT SWITCHING
4								21014046	D		TEST CABLES W1,W2,W3,W9,W10,W11,W12
5								21016947	D		SYSTEM INTERCONNECT DIAG TEST
6								21016948	D		SYSTEM INTERCONNECT DIAG FLIGHT
7	X										ASSY, BENCH TEST SET
8		X						21015284-101	D		CHASSIS, BENCH TEST SET
9		X						5283-101	D		FRONT PANEL BENCH TEST SET
10		X						5282-101	C		NUT BAR
11		X						5281-101	C		CHASSIS SUPPORT
12		X						5280-101	B		TERMINAL BOARD
13		X						5279-101	B		TERMINAL BLOC SPACER

CTS DWG & PARTS LIST

ITEM	ASSY LEVEL 1	2	3	4	5	6	7	DWG. NO.	SIZE	REF. DESIG.	TITLE
1								AK25A1			INSTALLATION DWG
-								6743	D		WIRING DIAGRAM EL Box
2	X							4944-101	E	UNIT 2	EL BOX ASSY
3		X						4299-101	E		CHASSIS, EL BOX
4		X						4298-101	D		BASE PLATE, EL BOX
5		X						4799-101	D		COVER, DUST
6		X						4797-101	D		COVER, ACCESS
7		X						4184-101	E		CARD RACK
8		X						4787-101	D		STIFFENER
9		X						4785-101	C		BKT, TRANFORMER
10		X						4796-101	C		COVER, ACCESS, PWR
11		X						4183-101	C		BAR KEEPER
12		X						4131-101	C		BRACKET, RELAY 115V
13		X						479[illegible]-101	C		BRACKET BUSS BAR
14		X						4132-101	B		BRACKET RELAY 28V
15		X						4182-101	B		SCREW, CAPTIVE
16		X						4798-101	B		POST, CLAMP
17		X						4863-101	D	A12	BUSS BAR ASSY
18			X					[illegible]-101	B		SPACER BUSS BAR
19			X					[illegible]-101	B		INSULATOR, BUSS BAR
20			X					[illegible]-101	B		BUSS STRIP GND
21			X					[illegible]-101	C		BUSS STRIP [illegible]

CTS DWG & PARTS LIST

ITEM	ASSY LEVEL 1	2	3	4	5	6	7	DWG. NO.	SIZE	REF. DESIG.	TITLE
—		X								2A8	BOARD ASSY SPARE
—			X								BOARD DETAIL " " "
—			X								SCHEMATIC " " "
22		X						4110	D	2A1	BOARD ASSY, VIDEO PROCESSOR
23			X					4109	D		BOARD DETAIL, " "
24			X					4108	D		SCHEMATIC " "
—		X						—		2A2	BOARD ASSY, VIDEO PROCESSOR
—			X								BOARD DETAIL, " "
—			X								SCHEMATIC " "
—		X								2A3	BOARD ASSY, VIDEO PROCESSOR.
—			X								BOARD DETAIL " "
—			X								SCHEMATIC " "

ITEM	ASSY LEVEL 1	2	3	4	5	6	7	DWG. NO.	SIZE	REF. DESIG.	TITLE
25		X						4189	D	2A4	BOARD ASSY, DEMOD TIMING + MUX
26			X					4188	D		BOARD DETAIL " "
27			X					4187	D		SCHEMATIC " "
28		X						4106	D	2A5	BOARD ASSY, MUX TIMING + CONTR[illegible]
29			X					4105	D		BOARD DETAIL "
30			X					4104	D		SCHEMATIC "
31		X						6976	D	2A6	BOARD ASSY, SIGNAL CONDITIONER
32			X					6975	D		BOARD DETAIL, " "
33			X					6974	D		SCHEMATIC " "
34		X						6971	D	2A7	BOARD ASSY, TM & CHOP COMP BUFF
35			X					6970	D		BOARD DETAIL " " " "
36			X					6969	D		SCHEMATIC " " " "

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CTS DWG + PARTS L

ITEM	ASSY LEVEL 1	2	3	4	5	6	7	DWG. NO.	SIZE	REF. DESIG.	TITLE
-		X								2A9	BOARD, ASSY, SPARE
-			X								BOARD DETAIL SPARE
-			X								SCHEMATIC SPARE
37		X						2285	D	2A10	BOARD ASSY, CHOPPER CONTROL
38			X					2284	D		BOARD DETAIL " "
39			X					2283	D		SCHEMATIC " "
40		X						2854	D	2A11	HEAT SINK ASSY
41			X					2853	D		CHASSIS, HEATSINK
42								4194	D		BOARD BLANK
43	X							6791	C	A13	BOARD ASSY, ISOLATION RESISTORS
44		X						6792	C		BOARD TERMINAL, ISOLATION RESISTORS
45	X							8260	C		BRACKET FILTER MTG

CTS DWG + PARTS LIST

ITEM	ASSY LEVEL 1	2	3	4	5	6	7	DWG. NO.	SIZE	REF. DESIG.	TITLE
1								JK25A1	E		INSTALLATION DWG, SCANNER
2								21016644	D		WIRING DIAGRAM, SCANNER
3	X							21012343-101	E	UNIT 1	ASSY, CLOUD TOP SCANNER
4		X						4836-101	D	1A1	DETECTOR ASSY CH 1
5			X					6960-101	D	1A1A1	BOARD ASSY, SILICONE DET PREAMP
6				X				6959-101	D	1A1A1 MP1	BOARD DETAIL, SILICONE DET PREAMP
7				X				6958-101	D	—	SCHEMATIC, SILICONE DET PREAMP
8			X					6985-101	C	1A1MP1	MOUNTING RING, CH1 PREAMP
9			X					6982-101	B	1A1MP2 – 1A1M[illegible]	SPACER, MALE-FEMALE
10			X					6981-101	B	1A1MP5	COVER, CH1 PREAMP
11			X					4045-101	D	1A1W1	CABLE ASSY
12		X						2318-102	E	1A2	DEWAR-HOUSING ASSY, CH 2
13			X					6990-102	E	1A2MP1	HOUSING DEWAR CH2
14			X					2281-102	D	1A2MP[illegible]	COVER, FILLING PORT
15			X					2282-101	C	1A2MP3	[illegible]ET
16			X					6963-102	D	1A2A2	BOARD ASSY, HCT PREAMP CH2
17				X				6962-101	D	1A2A2MP2	BOARD DETAIL, HCT PREAMP CH2
18				X				6961	D	—	SCHEMATIC, HCT PREAMP
19			X					2287-101	D	1A2MP4	COVER, PREAMP
20			X					1789-102	D	1A2A1	DETECTOR-DEWAR ASSY

CTS DWG + PARTS LIST

ITEM	ASSY LEVEL 1	2	3	4	5	6	7	DWG. NO.	SIZE	REF. DESIG.	TITLE
–			X					4045-102	–	1A2W1	CABLE ASSY
21			X					4180-101	B	1A2MP5	GASKET DEWAR WINDOW
–		X						2318-101	–	1A3	DEWAR-HOUSING ASSY CH 3
–			X					6990-101	–	1A3MP1	HOUSING, DEWAR, CH3
–			X					2281-101	–	1A3MP2	COVER FILLING PORT
–			X					2282-101	–	1A3MP3	GASKET
–			X					6963-101	–	1A3A2	BOARD ASSY, HCT PREAMP CH3
–				X				6962-101	–	1A3A2MP1	BOARD DETAIL, HCT PREAMP CH3
–				X				6961	–	–	SCHEMATIC, HCT PREAMP
–			X					2287-101	–	1A3MP4	COVER, PREAMP
–			X					1789-101	–	1A3A1	DETECTOR-DEWAR ASSY
–			X					4045-103	–	1A3W1	CABLE ASSY
–			X					4133-101	–	1A3MP5	GASKET, DEWAR WINDOW
22		X						4891-101	D	1A4	ASSY, SCAN MIRROR
23			X					6957-101	D	1A4A1	BOARD ASSY, SCAN MOTOR CONTROL
24				X				6956-101	E	1A4A1MP1	BOARD DETAIL, SCAN MOTOR CONTROL
[illegible]				X				6955	D	–	SCHEMATIC, SCAN MOTOR CONTROL
[illegible]			X					43[illegible]-101	E	1A4A2	HEAT SINK ASSY, SCAN MOTOR CONTROL
27				X				4795-101	E	1A4A2[illegible]	[illegible] HEAT SINK, SCAN MOTOR CONTROL

CTS DWG & PARTS LIST

ITEM	ASSY LEVEL 1	2	3	4	5	6	7	DWG. NO.	SIZE	REF. DESIG.	TITLE
28			X					4862-101	C	1A4A3	SLIP RING ASSY
29				X				2823-101	C	1A4A3MP1	SLIP RING MOUNT
30				X				2822-101	B	1A4A3MP2	SPACER, SLIP RING
31			X					4886-101	D	1A4A4	YOKE ASSY
32				X				2824-101	C	1A4A4MP1	YOKE BRUSH HOLDER
33			X					6938-101	D	1A4A5	ENCODER
34			X					4861-101	C	1A4B1	TORQUE MOTOR
35			X					1767-101	D	1A4A6	HOUSING ASSY
36				X				6986-101	D	1A4A6MP1	ENCODER HOUSING
37				X				2951-101	D	1A4A6MP2	ENCODER MOUNT
38			X					4100-101	D	1A4A7	SHAFT ASSEMBLY
39				X				2831-101	D	1A4A7MP1	SHAFT
40				X				29[illegible]-101	C	1A4A7MP2	SPACER
41				X				2895-101	B	1A4A7MP3	RETAINER, BEARING
42			X					2931-101	C	1A4MP1	RETAINER, STATOR
43			X					2896-101	B	1A4MP2	RETAINER, BEARING
44			X					2949-101	C	1A4MP3 1A4MP4	RETAINER ENCODER
45			X					6932-101	D	1A4MP5	SCAN MIRROR
46			X					4127-101	C	1A4MP6	WASHER-SPHERICAL (CONCAVE)
—			X					4127-102	—	1A4MP7	WASHER SPHERICAL (CONVEX)
116			X					7444-10	C	1A4A7	BOARD ASSY, ENCODER TRANSMITTER
117				X				7443-10	B	1A4A7MP1	TERMINAL BOARD

CTS DWG & PARTS LIST

ITEM	ASSY LEVEL 1	2	3	4	5	6	7	DWG. NO.	SIZE	REF. DESIG.	TITLE
47		X						6941-101	D	1A5	OUTLINE DWG, . HOT BLACKBODY
-		X						6941-102	-	1A6	OUTLINE DWG, COLD BLACKBODY
48		X						6979-101	E	1A7	CHOPPER ASSY
49			X					6973-101	D	1A7A1	PICKOFF ASSY
50				X				6972-101	C	1A7A1MP1	HOUSING, CHOPPER PICKOFF
51			X					6968-101	D	1A7A2	BOARD ASSY, CHOPPER PICKOFF
52				X				6967-101	D	1A7A2MP1	BOARD DETAIL, CHOPPER PICKOFF
53				X				6966	B	—	SCHEMATIC, CHOPPER PICKOFF
54			X					6937-101	C	1A7B1	CHOPPER MOTOR
55			X					6953-101	D	1A7MP1	HOUSING CHOPPER
56			X					6949-101	C	1A7MP2	CHOPPER WHEEL
57			X					6952-101	C	1A7MP3	COVER, CHOPPER WHEEL
58			X					6950-101	B	1A7MP4	MOUNTING FLANGE, CHOPPER WHEEL
59		X						4140-101	D	1A8	CAPACITOR ASSY
60			X					4141-101	D	1A8MP1	CHASSIS, CAP MTG
61			X					4142-101	C	1A8MP2	COVER PROTECTIVE

CTS DWG & PARTS LIST

ITEM	ASSY LEVEL 1	2	3	4	5	6	7	DWG. NO.	SIZE	REF. DESIG.	TITLE
62		X						4848-101	D	1A9	SECONDARY MIRROR ASSY
–			X					6930-802	–	1A9MP1	MIRROR SECONDARY (M3)
63			X					6965-101	E	1A9MP2	SPIDER
64			X					6930-101	D	–	ALIGNMENT M2-M3 MIRRORS
65				X				69[illegible]-101	D	–	MIRROR PRIMARY (M2)
66				X				6935-101	D	–	MIRROR SECONDARY (M3)
67		X						6964-101	C	1A10	BEAMSPLITTER ASSY CH1
68			X					6940-101	C	1A10MP1	BEAMSPLITTER CH1
69			X					6945-101	C	1A10MP2	HOUSING, BEAMSPLITTER CH1
70			X					4293-101	B	1A10MP3 1A10MP4	CLAMP, BEAMSPLITTER
–		X						6964-102	–	1A11	BEAMSPLITTER ASSY CH3
71			X					6939-101	C	1A11MP1	BEAMSPLITTER CH3
72			X					6944-101	C	1A11MP2	HOUSING, BEAMSPLITTER CH3
–			X					4293-101	–	1A11MP3 – 1A11MP6	CLAMP, BEAMSPLITTER

CTS DWG & PARTS LIST

ITEM	ASSY LEVEL 1	2	3	4	5	6	7	DWG. NO.	SIZE	REF. DESIG.	TITLE
73		X						6931-101	D	1A12	ASSY, CH1 OPTICS
74			X					6908-101	D	1A12 MP1	LENS HOUSING INNER
75			X					6916-101	B	1A12 MP2	GASKET, LENS
76			X					6900-101	C	1A12 MP3	CONVEX LENS, CH 1
77			X					6910-101	C	1A12 MP4	SPACER, LENS, FWD, NO. 1
78			X					6905-101	B	1A12 MP5	COMPENSATING POLARIZER
79			X					6911-101	C	1A12 MP6	SPACER, LENS, FWD, NO 2
80			X					6909-101	D	1A12 MP7	LENS HOUSING, OUTER
81			X					6904-101	B	1A12 MP8	FILTER CH1
82			X					6915-101	B	1A12 MP9	SPACER, LENS REAR
83			X					6901-101	C	1A12 MP10	LENS CH1
–			X					6901-102	–	1A12 MP11	LENS CH1
84			X					6913-101	B	1A12 MP12	LENS MOUNT
85			X					6912-101	B	1A12 MP13	LENS RETAINER
86			X					6914-101	B	1A12 MP14	SPACER LENS MOUNT
87		X						6980 101	E	1MP1	HOUSING, TELESCOPE (MACHINING)
88			X					6942-101	E	—	CASTING, TELESCOPE HOUSING
89		X						6951-101	D	1MP2	PLATE, MTG, PRIMARY MIRROR
90		X						6943-101	E	1MP3	BEAMSPLITTER MOUNT

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ITEM	ASSY LEVEL 1	2	3	4	5	6	7	DWG. NO.	SIZE	REF. DESIG.	TITLE
91		X						6954-101	C	IMP4	FIELDSTOP
92		X						6984-101	C	IMP5	SHIM, CH.1 DETECTOR ASSY
93		X						6983-101	B	IMP6 – IMP8	WASHER SPECIAL
94		X						6936-101	D	IMP9	SUPPORT, CH 1
95		X						2341-101	D	IMP10	CLAMP, CH1 OPTICS
96		X						2342-101	C	IMP11	CLAMP, SPLIT RING, CH 1 OPTICS
97		X						6922-101	E	IMP12	LENS HOUSING. CH 2
98		X						6902-101	C	IMP13	LENS CH 2
–		X						6902-102	–	IMP14	LENS CH2
99		X						6921-101	C	IMP15	SPACER, LENS
–		X						6921-102	–	IMP16	SPACER, LENS
100		X						6926-101	B	IMP17	SPACER FILTER
101		X						6906-101	C	IMP18 IMP19	FILTER CH2
102		X						6919-101	C	IMP20	ADAPTER LENS MTG, CH 2
103		X						6918-101	C	IMP21	CLAMP LENS CH 2
104		X						6920-101	C	IMP22	MIRROR MOUNTING PLATE, CH2
105		X						6939-101	C	IMP23	MIRROR, FLAT
–		X						6916-102	–	IMP24 IMP25	GASKET, LENS

CTS DWG & PARTS LIST

ITEM	ASSY LEVEL 1	2	3	4	5	6	7	DWG. NO.	SIZE	REF. DESIG.	TITLE
–		X						6921-103	–	IMP26	SPACER LENS, (CH3)
–		X						6921-104	–	IMP27	SPACER LENS (CH3)
–		X						6905-101	–	IMP28	SPACER FILTER (CH 3)
106		X						6907-101	C	IMP29 IMP30	FILTER, CH3
107		X						6903-101	C	IMP31	LENS CH3
–		X						6903-102	–	IMP32	LENS CH3
108		X						2317-101	D	IMP33	MOUNTING PLATE, CH3 OPTICS
–		X						6916-102	–	IMP34	GASKET LENS
109		X						2347-101	C	IMP35 IMP36	SHIM, DEWAR
110		X						6988-101	D	IMP37	COVER OPTICS COMPARTMENT
111		X						6978-101	B	IMP38 IMP39	ECCENTRIC
112		X						6989-101	C	IMP40	PLATE CONNECTOR MTG (16)
–		X						6989-102	–	IMP41 IMP42	PLATE CONNECTOR MTG (14)
–		X						6989-103	–	IMP43	PLATE CONNECTOR MTG (12)
113		X						2826-101	B	IMP44	BRACKET CONNECTOR
114		X						6977-101	B	IMP45 – IMP47	SHIM, SPIDER
115		X						6987-101	B	IMP48 IMP51	ISOLATOR
–		X						6930-801	–	IMP52	PRIMARY MIRROR
116											
117											

CTS DWG + PARTS LIST

ITEM	ASSY LEVEL 1	2	3	4	5	6	7	DWG. NO.	SIZE	REF. DESIG.	TITLE
1								F-33-001	C		HOUSING, CHOPPER MOTOR
2								F-33-002	C		PLATE, MTG, CHOPPER
3								F-33-003	C		CHOPPER WHEEL
4								F-33-004	B		FLANGE, MTG, CHOPPER
5								T-33-005	C		MOLD, BUSS BAR
6								T-33-006	B		POST, MTG, SCANNER
7								F-33-007 THRU F-33-011	D		MTF TARGET
8								F-33-012	C		BRACKET MTG, MTF TARGET
9								F-33-013	C		BRACKET MTG, MTF SOURCE
10								F-33-014	C		MTF SOURCE
11								F-33-015	C		PLATE MTG, MTF TARGET
12								F-33-016	C		CLAMP, MTF TARGET
13								F-33-017 + F-33-018	C		ALIGNMENT TARGET
14								F-33-019	D		TEST FIXTURE SHOCK + VIBRATION

PURCHASED PARTS

ITEM	DESCRIPTION	MFG	PART NO.	QTY	USED ON
1	HEATER (14.55 W) (2.04 × 1.28)	MINCO	HK5101A 909	5	4 ON SCAN MIRROR, 1 ON SECONDARY MIRROR
2	HEATER (78.25W) (4.00 DIA)	MINCO	HK5117A 169	4	2 ON TELESCOPE, 2 ON RELAY OPTICS
3	HEATER (37.39W) (3.03 SQ)	MINCO	HK5118A 350	3	3 ON SERVO HOUSING
4	HEATER CEMENT	MINCO	TYPE NO. 6	—	BONDING HEATERS
5	TERMINAL BLOCK (PC 8 TERM)	KULKA	520-31	2	SCAN MOTOR CONTROL PC
6	TERMINAL BLOCK (3 TERM)	KULKA	410-3/4 ST-3SS	1	CHOPPER TEMP SENSOR
7	TERMINAL BLOCK (4 TERM)	KULKA	410-3/4 ST-4SS	3	SCAN MIRROR ASSY + 2nd MIRROR ASSY HEATERS & SCAN MOTOR HS
8	TERMINAL BLOCK (6 TERM)	KULKA	410-3/4 ST-6SS	2	PWR DIST FOR HEATERS + CAPACITOR ASSY
9	TERMINAL BLOCK (7 TERM)	KULKA	410-3/4 ST-7SS	2	EL BOX 28V PWR DIST + SCAN MOTOR HS
10	MARKER STRIP	KULKA	MS410-3-GEE	1	USE WITH ITEM 6
11	MARKER STRIP	KULKA	MS410-4-GEE	3	USE WITH ITEM 7
12	MARKER STRIP	KULKA	MS410-6 GEE	2	USE WITH ITEM 8
13	MARKER STRIP	KULKA	MS410-7 GEE	2	USE WITH ITEM 9
14	TAPER PIN, THREADED #0 × .75LG		STD 21933009-143	21	GENERAL USE
15	TAPER PIN #0 × .75LG	—	—	2	SCAN MIRROR ASSY
16	LOCKNUT, SELF ALIGN 3/8-24UNF-3B	ESNA	52 LH4367-064	2	SCAN MIRROR ASSY
17	WASHER SELF-ALIGN	ESNA	4367-06	2	SCAN MIRROR ASSY
18	BEARING, DEEP GROOVE DUPLEX PAIR (DB) 1.125 OD .5000 ID	NH BALL BEARING	SR8 FCK58-1	2 PAIR	SCAN MIRROR ASSY
19	SLIP RING	GRAPHALLOY	1165-27	2	SCAN MIRROR ASSY
20	BRUSH HOLDER	GRAPHALLOY	11509	4	SCAN MIRROR ASSY
22	BRUSH + SPRING ASSY w/SHUNT	GRAPHALLOY	131-5-39411 (MOD FOR 1165-27 RING)	4	SCAN MIRROR ASSY
23					
24	SERVO MOTOR	MAG TECH	2703-060	1	SCAN MIRROR ASSY

PURCHASED PARTS

ITEM	DESCRIPTION	MFG	PART NO.	QTY	USED ON
25	ENCODER	BALDWIN	HSN PART NO 21016438	1	SCAN MIRROR ASSY
26	TERMINAL	AMATOM	SE12-X-C-04		ALL PC BOARDS
27	TERMINAL	AMATOM	SE15-X-C-04		ALL HARD WIRED BOARDS
28	TERMINAL INSULATED	CTC	4810-1-05-16		SCAN MIRROR HS
29	TERMINAL INSULATED	CTC	4920-1-05-16		EL BOX
30	TERMINAL INSULATED	CTC	1980-XA250	50	TS CONNECTIONS
31	VALVE CONSTANT PRESSURE	TAVCO	2391243-3-4	[illegible]	DEWAR ASSY
32	LINK LOCK FASTENER	SIMMONS	NO.3 LINK LOCK	2	DEWAR ASSY
33	HINGE LOCK FASTENER	SIMMONS	1183 HINGE LOCK	2	DEWAR ASSY
34	TERMINAL, TUBULAR, HERMETIC	EI	AAAS-40T-5X	10	DEWAR ASSY
35	NIPPLE, MALE PIPE	CAJON	B-4-HN	2	DEWAR ASSY
36	SCREW SHOULDER	PIC	4311	4	BEAMSPLITTER ADJ
37	SCREW SHOULDER	PIC	4312	4	BEAMSPLITTER ADJ
38	WAVE WASHER		U125-0040	8	BEAMSPLITTER ADJ
39	MOTOR, CHOPPER		21016437	1	CHOPPER ASSY
40	CONNECTOR FEMALE	MALCO	MCDM1-95S	1	CHOPPER CABLE
41	CONNECTOR MALE 9PIN	MALCO	MCDM1-9S	1	CHOPPER ASSY
42	LED	MONSANTO	ME 7124	1	CHOPPER ASSY
43	FEMALE JACKSCREW ASSY	MALCO	096-3332-0009	2	CHOPPER ASSY
44	MALE JACKSCREW ASSY	MALCO	096-3332-0010	2	CHOPPER CABLE
45	PHOTO DIODE	UDT	[illegible] 020A	1	CHOPPER AS
46	THERMOSTAT	TI (KLIX)	3ET-6	1	TELESCOPE
47	[illegible]				CHOPPER [illegible] HELMY OPTICS

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PURCHASED PARTS

ITEM	DESCRIPTION	MFG	PART NO.	QTY	USED ON
48	CARD GUIDES	UNITRACK	RADGB7	20	EL BOX
49	CAMBI CARD	CTC	715-1101-01-00-00	8 MIN 10 MAX	EL BOX
50	CAMBI CARD	CTC	715-1116-01-00-00	2	EL BOX
51	EXTENDER CARD	CTC	715-1100-01-00-00	2	TEST
52	CONNECTOR 70 PIN	CTC	706-7079-01-00-00	10	EL BOX
53	KEY POLARIZING	CTC	706-1001-01-00-19	10	EL BOX
54	RELAY	BABCOCK	BR7X-30002-26V	6	EL BOX + CAP ASSY
55	ELAPSED TIME INDICATOR	AW HAYDON	KT19723-F4	1	EL BOX
56	TRANSFORMER			2	EL BOX
57	POWER SUPPLY ±5V			1	EL BOX
58	POWER SUPPLY ±10V			1	EL BOX
59	POWER SUPPLY ±15V			1	EL BOX
60	POWER SUPPLY ±30V			1	EL BOX
61	FILTER EMI DC	ERIE	1215-095	6	EL BOX
62	FILTER EMI AC	ERIE		4	EL BOX
63	RING TERMINAL, INSULATED 26-22 AWG	WALDOM	N-5926	24	SCAN MOTOR PC & 24-26AWG WIRE ON 410 SERIES TB
64	RING TERMINAL INSULATED 18-22 AWG	WALDOM	N-5099	50	USE WITH 410 SERIES TB w/22-20 AWG WIRE
65	RING TERMINAL INSULATED 26-22 AWG	WALDOM	N-5939	24	FOR CHASSIS GND @ CONNECTORS
66	RING TERMINAL INSULATED 16-14 AWG	WALDOM	N-5102	12	USE WITH 410 SERIES TB w/16 AWG WIRE
67	RING TERMINAL INSULATED 18-22 AWG	WALDOM	N-5301	12	USE WITH MAIN GROUND STUD
68	LOCKTITE GRADE C				GENERAL
69	STANDOFF	AMATOM	8218-SS-0440	3	CAPACITOR ASSY

APPENDIX D

VIBRATION TEST REPORT

Test Report No. 12997 No. of Pages 35

Report of Test on

VIBRATION TESTING
OF CLOUD TOP SCANNER
FOR HONEYWELL, INC.
UNDER PURCHASE ORDER NO. BX96376

ACTON ENVIRONMENTAL TESTING CORPORATION

Date February 4, 1977

	Prepared	Checked	Approved
By	A.LeBourdais	M.Casaubon	M.L.Tolf
Signed	A. LeBourdais	M. Casaubon	M. L. Tolf
Date	2/4/77	2/4/77	2/4/77

MLT:AWL/hmf

Administrative Data

1.0 Purpose of Test: To subject Cloud Top Scanner and Cloud Top Scanner fixture to vibration testing and evaluation.

2.0 Manufacturer:

Honeywell, Inc.

3.0 Manufacturer's Type or Model No: Item identified as Cloud Top Scanner.

4.0 Drawing, Specification or Exhibit: Per Honeywell, Inc. representative's instructions. (See requirements and procedures herein).

5.0 Quantity of Items Tested:

One (1)

6.0 Security Classification of Items:

Unclassified

7.0 Date Test Completed: January 28, 1977

8.0 Test Conducted By:

D.McLaughlin

9.0 Disposition of Specimens: Returned to Honeywell, Inc.

10.0 Abstract:

Evaluation of the fixture and scanner was made by Honeywell, Inc. representative.

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ENVIRONMENTAL ACTON TESTING CORPORATION

1.0 REQUIREMENTS

The Cloud Top Scanner test fixture with dummy load shall be subjected to a sinusoidal survey. Following this sinusoidal survey, the Cloud Top Scanner shall be subjected to sinusoidal vibration exposures in the vertical and longitudinal axes. These tests are as detailed in procedures herein.

2.0 PROCEDURES

Per Honeywell, Inc. representative's instructions, 12-accelerometers, 2-visicorders and a magnetic tape system were utilized for this vibration test program.

The following test program was performed under the direction of Honeywell, Inc. representative:

TEST NO. 1

The fixture was secured for vibration testing in the vertical axis. A dummy load supplied by Acton Environmental Testing Corporation(AETC) was secured to the test fixture. Six accelerometers were attached and were recorded, utilizing a Minneapolis-Honeywell Visicorder. The test fixture/dummy load configuration was then subjected to a sinusoidal vibration test from 20-2000 Hz at a 1g level and at a sweep rate of 2 octaves/minute. Following this survey in the vertical axis, Test No. 2 was performed.

TEST NO. 2

Vertical axis - Cloud Top Scanner attached to test fixture. 12-accelerometers were utilized and the 2-visicorders and the magnetic taping system was utilized. The following test was performed:

20-120 Hz @ 1g

120-180 Hz @ .2g

180-850 Hz @ 1g

850-1050 Hz @ .5g

1050-2000 Hz @ 1g

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Sweep rate during test was at 2 octaves/minute

Following Test No. 2, direction of vibration was changed to longitudinal and Test No. 3 was performed.

TEST NO. 3

Longitudinal axis - test fixture and dummy load. Six accelerometers and a visicorder were utilized for this test. Test was from 20 to 2000 Hz at a 1g level and at a sweep rate of 2 octaves/minute. Following this test, the Cloud Top Scanner was mounted to the test fixture and Test No. 4 was performed.

TEST NO. 4

Longitudinal axis - Cloud Top Scanner. Twelve accelerometers were utilized, 2-visicorders and a magnetic tape system. The following test was performed:

20 - 120 Hz @ 1g

120-180 Hz @ .3g

180-340 Hz @ 1g

340-480 Hz @ .5g

480-2000 Hz @ 1g

Sweep rate during test was at 2 octaves/minute.

NOTE: DURING THE FIRST RUN OF TEST NO. 4, THE VIBRATION AMPLIFIER DROPPED OUT AT 50 Hz. TEST WAS STOPPED AND TEST NO. 4 WAS RE-STARTED FROM THE 20 Hz frequency.

During vibration testing of the Cloud Top Scanner, the Cloud Top Scanner was operated and monitored by Honeywell, Inc. representatives. All visicorder recordings generated during vibration testing were retained by Honeywell, Inc. representatives. The magnetic tape recordings of Runs #2 and 4 were analyzed by Acton Environmental Testing Corporation and are included with this report.

Report No. 12997

3.0 RESULTS

Evaluation of the test fixture and Cloud Top Scanner during and after vibration exposures was performed by Honeywell, Inc. representatives.

Report No. 12997

ENVIRONMENTAL
ACTON TESTING
CORPORATION

4.0 TEST EQUIPMENT LIST

NAME	MFGR.	MODEL	SER.NO.	RANGE	ACCURACY	INV.#	CAL. FREQ
Accelerometer	B&K	8302	502634	1 Hz - 5 KHz	±5%	AC317	3 months
"	"	"	344783	"	"	AC318	" "
"	"	"	502630	"	"	AC320	" "
"	"	"	450710	"	"	AC323	" "
"	BK1	4335	170868	2 Hz - 6 KHz	±2%	AC325	" "
"	"	8302	472976	1 Hz - 5 KHz	±5%	AC329	" "
"	"	"	472989	"	"	AC336	" "
"	B&K1	4335	361763	2 Hz - 8 KHz	±2%	AC353	" "
"	"	"	135360	"	"	AC357	" "
"	"	"	362079	"	"	AC370	" "
"	"	"	362084	"	"	AC372	" "
"	BK	4344	611004	2 Hz - 25 KHz	"	AC445	" "
Exciter Amplifier	Ling "	A249 PP120/150	70 56	30,000# force 1"P/P disp. 5 Hz - 5 KHz	±5% ±2%	PE317	1 month
Log Converter	Moseley	60D	299	0-60 DB	±0.5 db	PE323	3 months
"	"	60B	844	"	"	PE324	" "
Log Converter Freq.	UD	LFC-5	104	5 Hz - 5 KHz	±2%	PE335	6 months
Charge Ampl-Auto	UD	11MGSA	102	1-1000G 2 Hz-20 KHz	±2%	PE341	" "
"	"	"	104	"	"	PE342	" "
"	"	"	105	"	"	PE343	" "
"	"	"	106	"	"	PE344	" "
"	"	"	109	"	"	PE345	" "
Charge Amplifier	"	D11MGSVW	E585	"	"	PE349	" "
"	"	"	E587	"	"	PE351	" "

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NAME	MFGR.	MODEL	SER.NO.	RANGE	ACCURACY	INV.#	CAL.FREQ.
Charge Amplifier	UD	D11MGSV	909	1-1000G 2 Hz-20 KHz	±2%	PE353	6 months
"	"	"	503	"	"	AC356	" "
"	"	"	917	"	"	AC363	" "
"	"	"	918	"	"	AC364	" "
"	"	"	924	"	"	AC365	" "
Visicorder	Honeywell	906C2	99334	DC to 2 KHz 12 channel	±1 DB	RE311	3 months
Recorder Tape	AMP	FR1300	7430293	14 channel FM 1" Tape 0-2.5 KHz	±0.5%	RE331	" "
Recorder	Honeywell	906C	99078	DC to 2 KHz 12 channel	±1db	RE335	" "
Recorder X-Y	HP	7035B	1206A06843	Input E=1,10,100 MV/IN 1,10 V/IN	±0.2%	RE336	" "
Recorder X-Y	MFE	715E	42167	Input:1-10-100 MV 1-10V Both channels	±0.5%	RE340	" "

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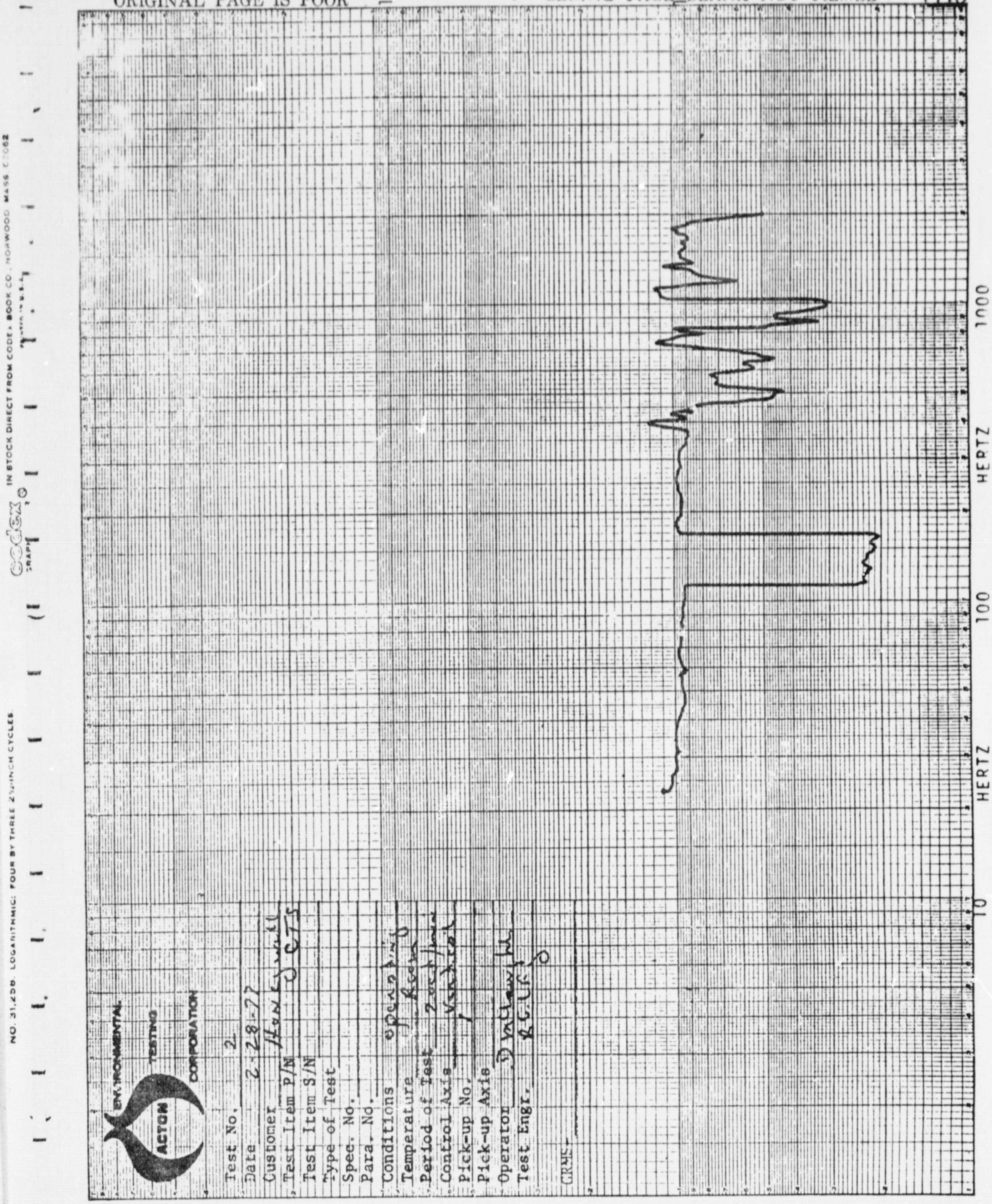

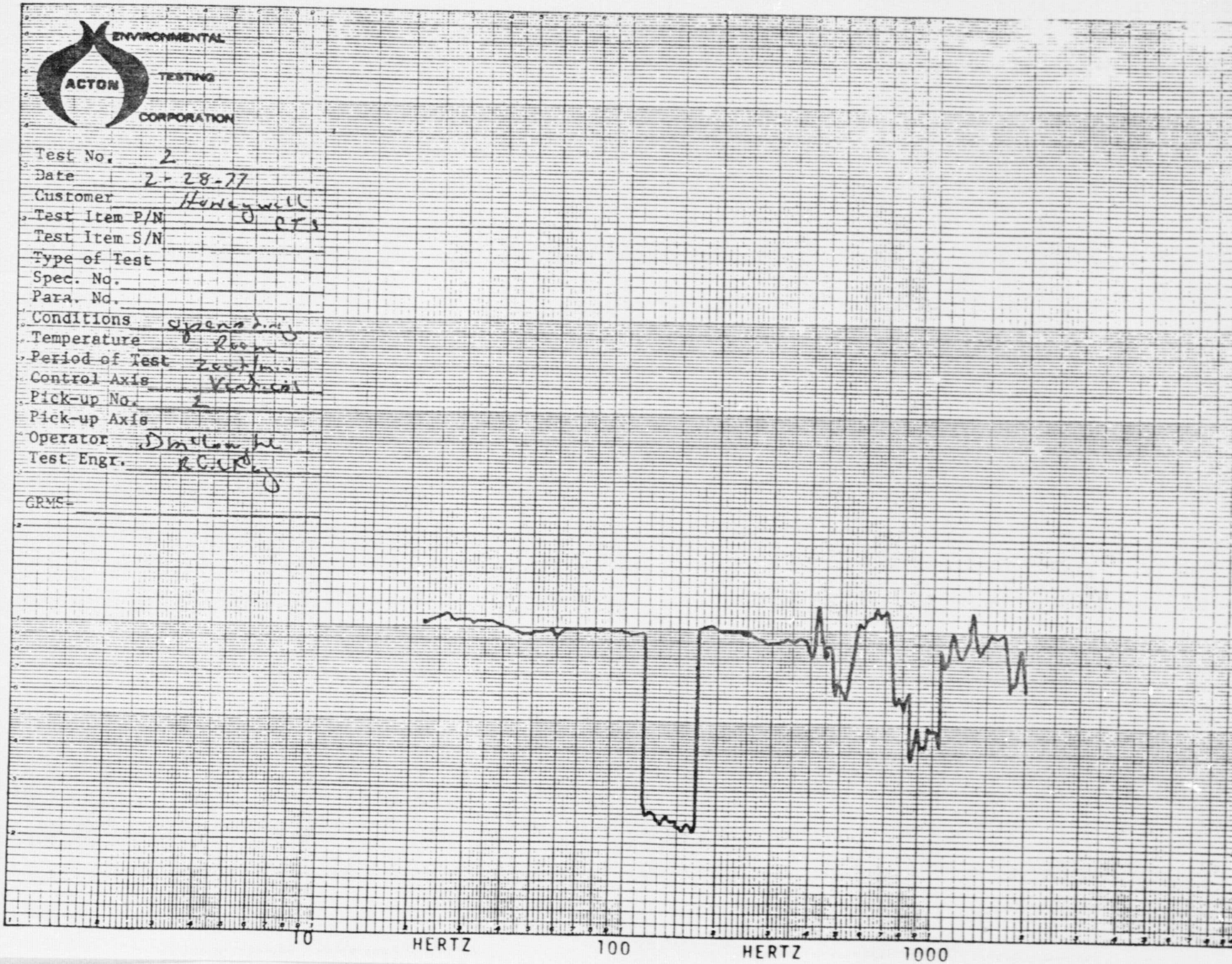
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ACTON
TESTING
CORPORATION
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Date 2-28-77
Customer Honeywell
Test Item P/N
Test Item S/N
Type of Test
Spec. No.
Para. No.
Conditions
Temperature Room
Period of Test
Control Axis Vertical
Pick-up No. 2
Pick-up Axis
Operator
Test Engr.
GRMS=
10
HERTZ
100
HERTZ
1000

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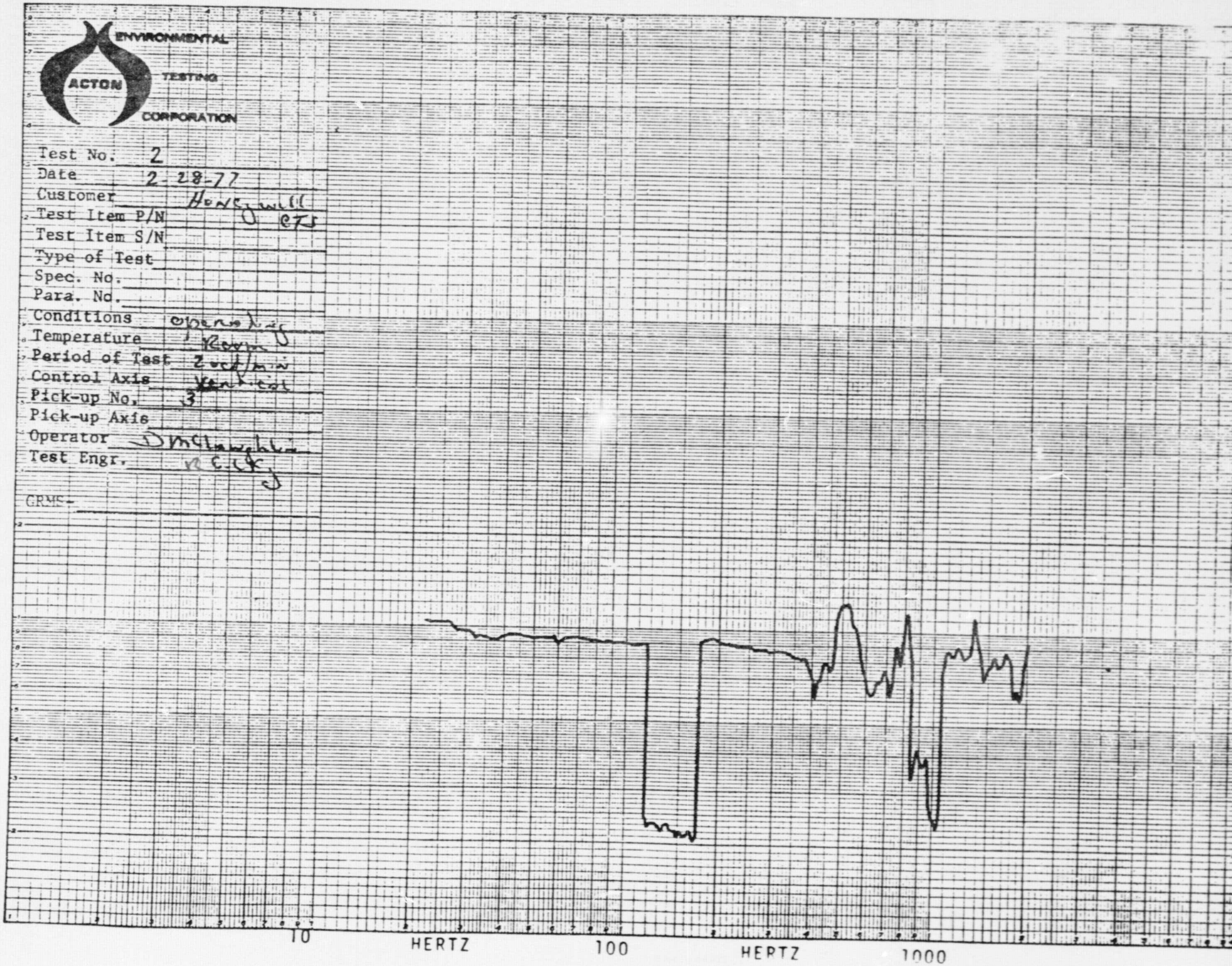
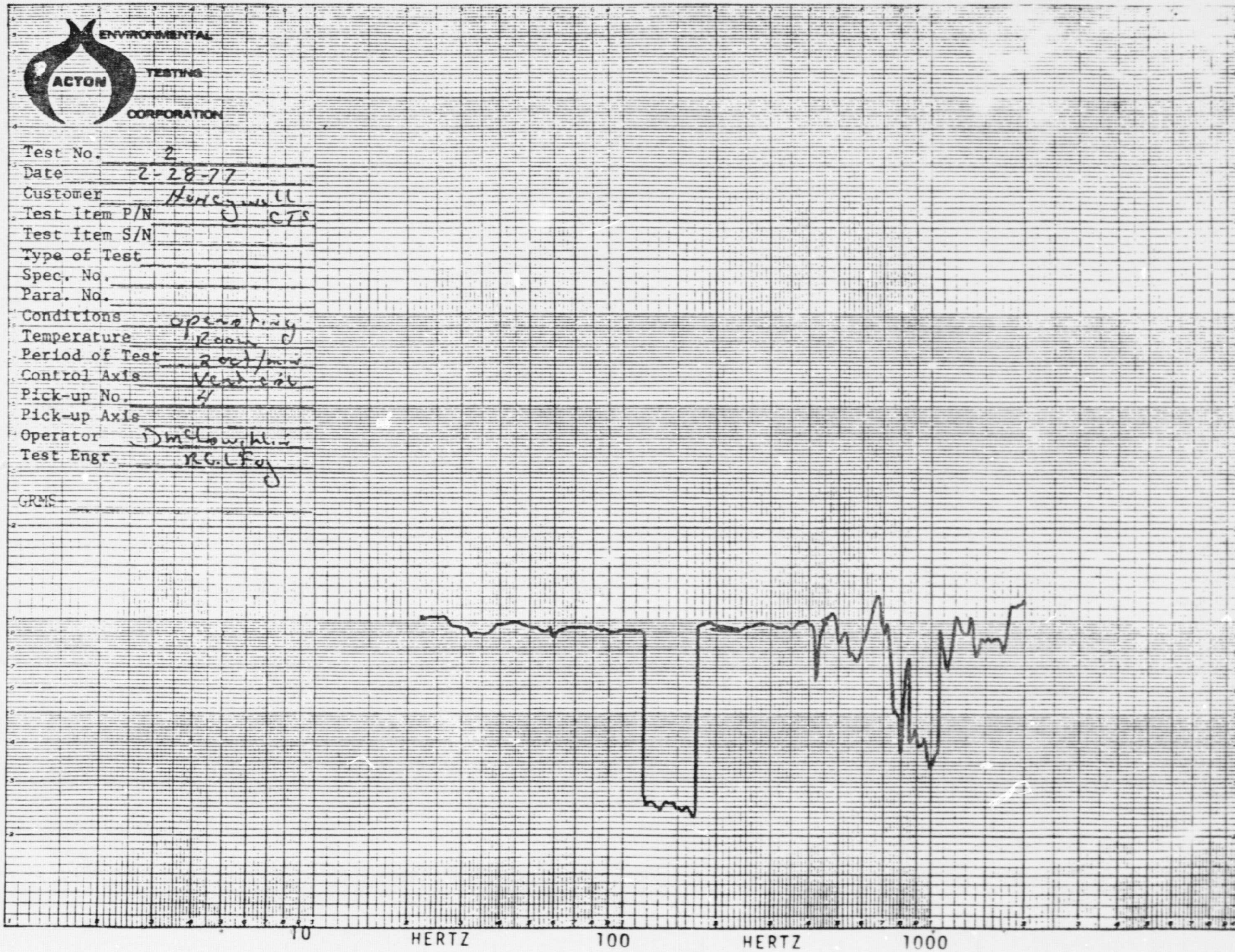
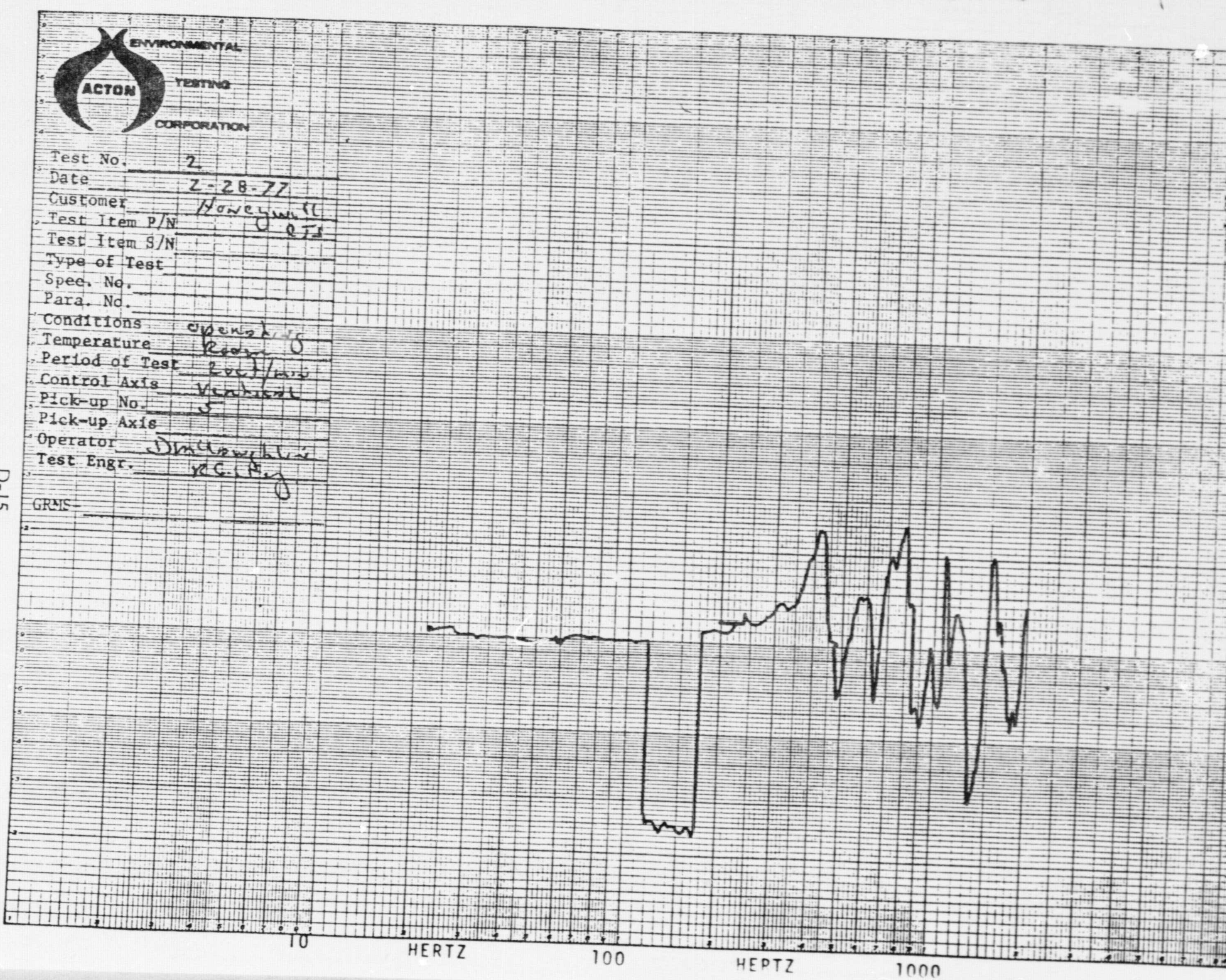
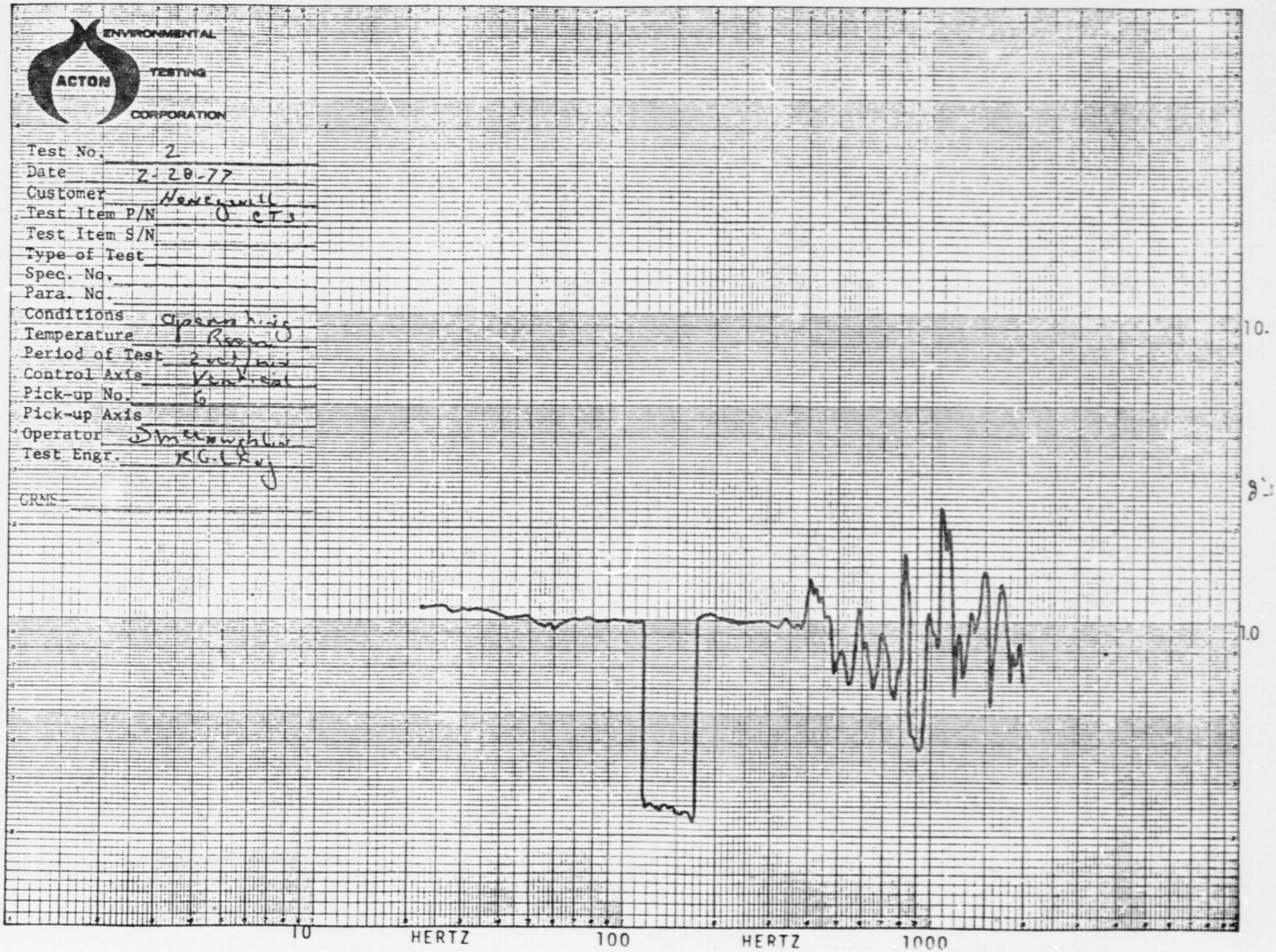



ENVIRONMENTAL
ACTON
TESTING
CORPORATION
Test No. 2
Date 2-28-77
Customer Honeywell
Test Item P/N
Test Item S/N
Type of Test
Spec. No.
Para. No.
Conditions operating
Temperature Room
Period of Test
Control Axis Vertical
Pick-up No. 4
Pick-up Axis
Operator
Test Engr.
GRMS
10.0
g
1.0
10
HERTZ
100
HERTZ
1000

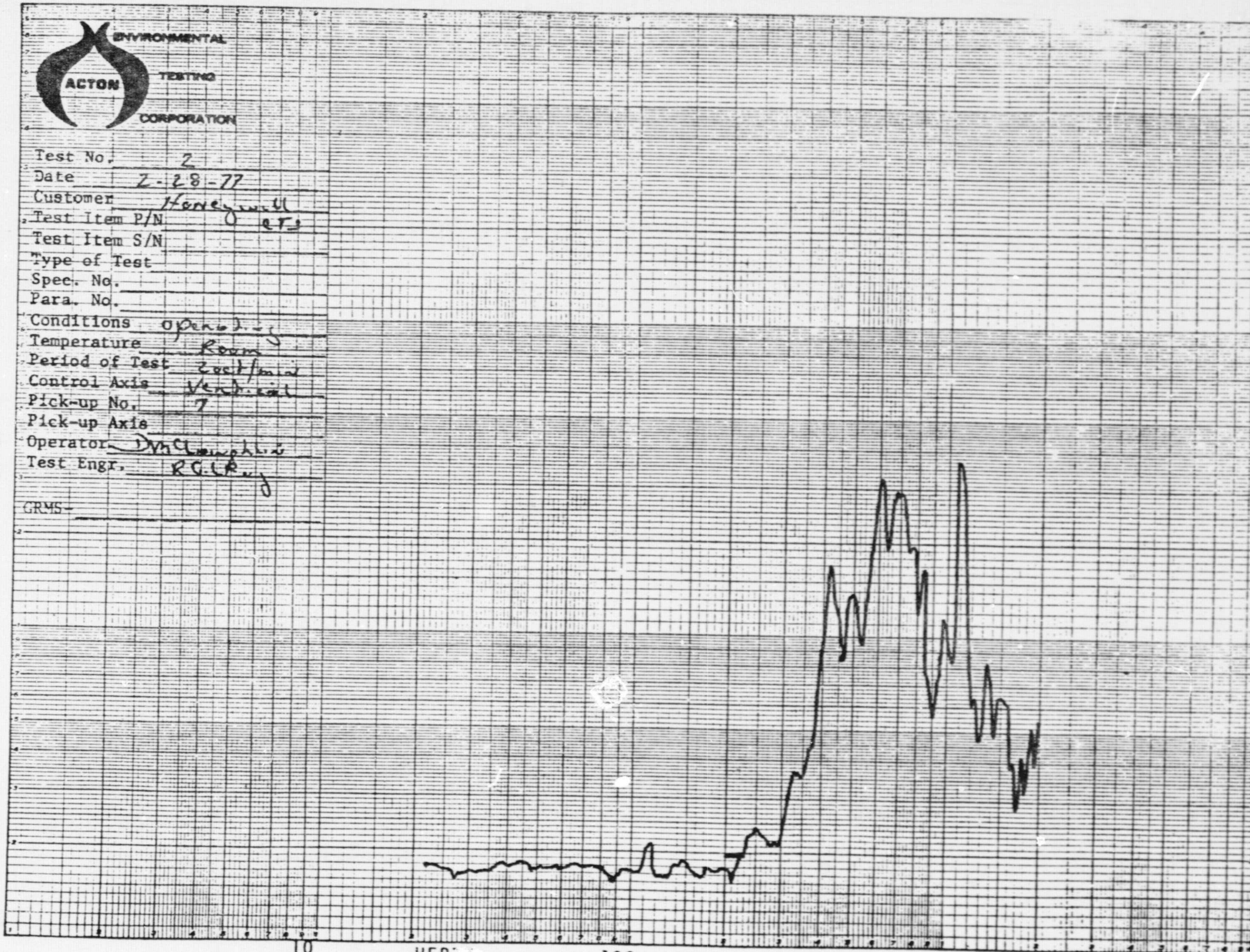
NO. 31,258. LOGARITHMIC: FOUR BY THREE 2½-INCH CYCLES.

CODEX GRAPH ® IN STOCK DIRECT FROM CODEX BOOK CO., NORWOOD, MASS. 02062




ACTON ENVIRONMENTAL TESTING CORPORATION
Test No. 2
Date 2-28-77
Customer Honeywell
Test Item P/N CTS
Test Item S/N
Type of Test
Spec. No.
Para. No.
Conditions Operating
Temperature Room
Period of Test 2 oct/min
Control Axis Vertical
Pick-up No. 6
Pick-up Axis
Operator Smallwood
Test Engr. R.G.
GRMS
10.
1.0
10
HERTZ
100
HERTZ
1000

NO. 31,258. LOGARITHMIC: FOUR BY THREE 2½-INCH CYCLES. CODEX GRAPH ® IN STOCK DIRECT FROM CODEX BOOK CO., NORWOOD, MASS. 02062 PRINTED IN U.S.A.



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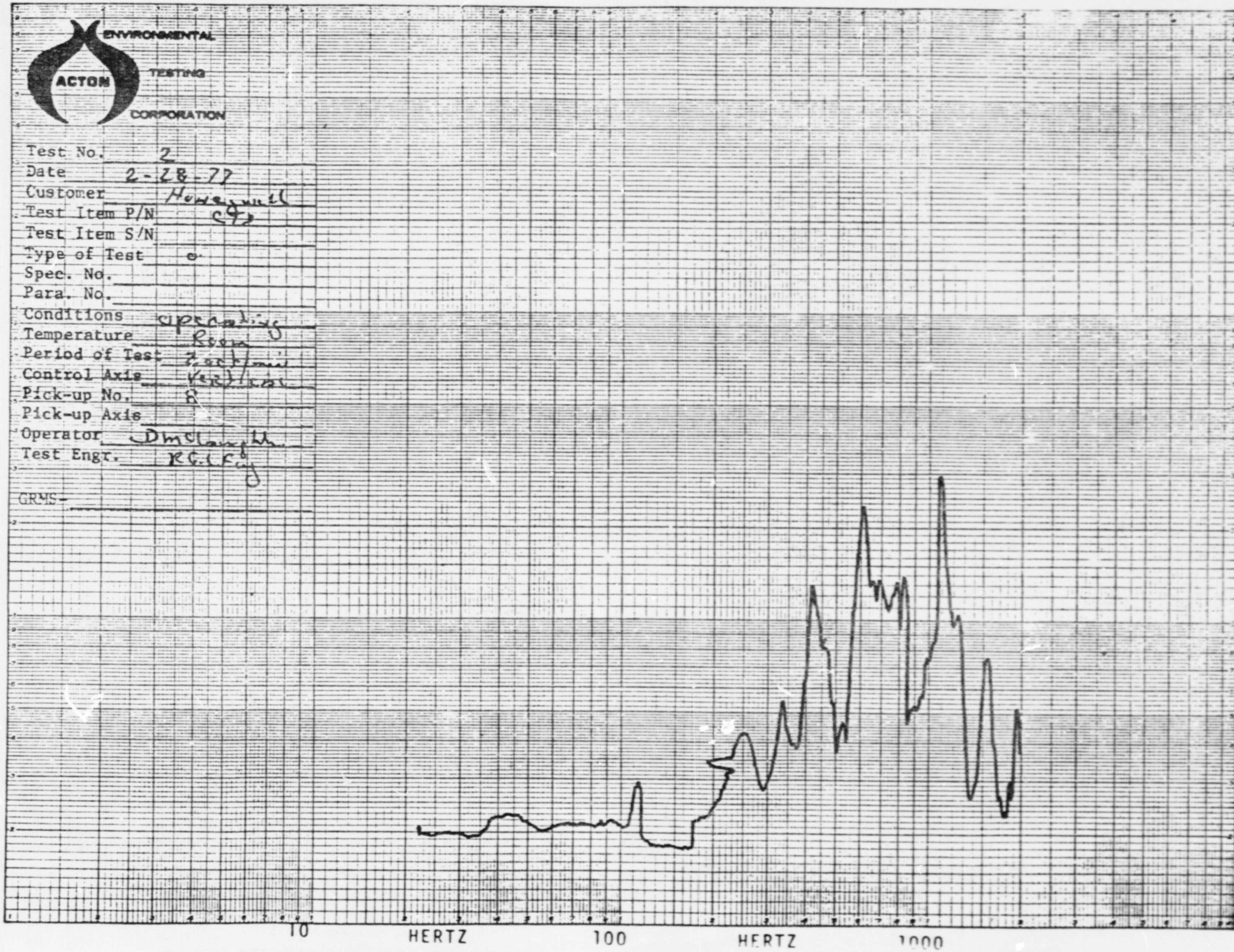

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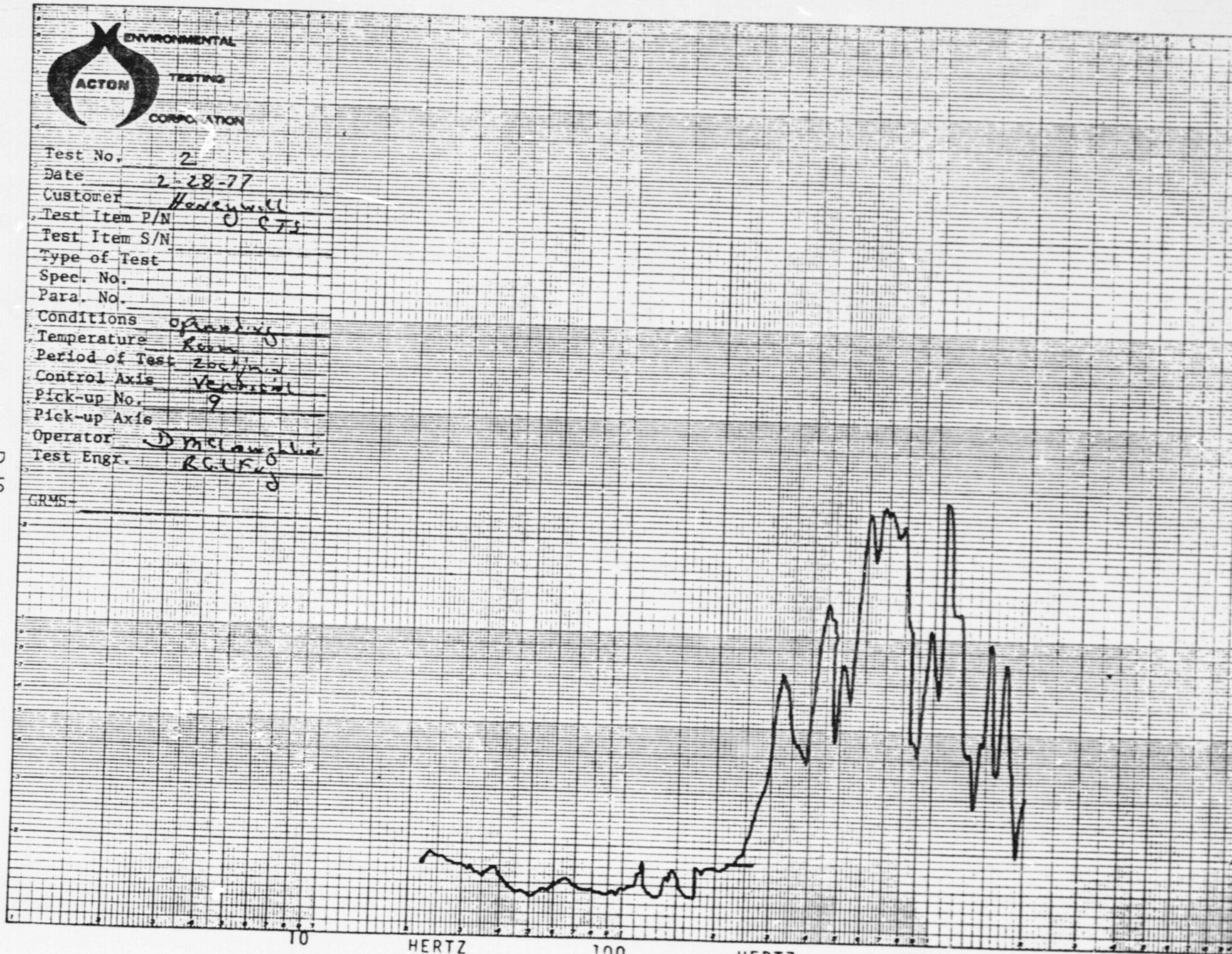

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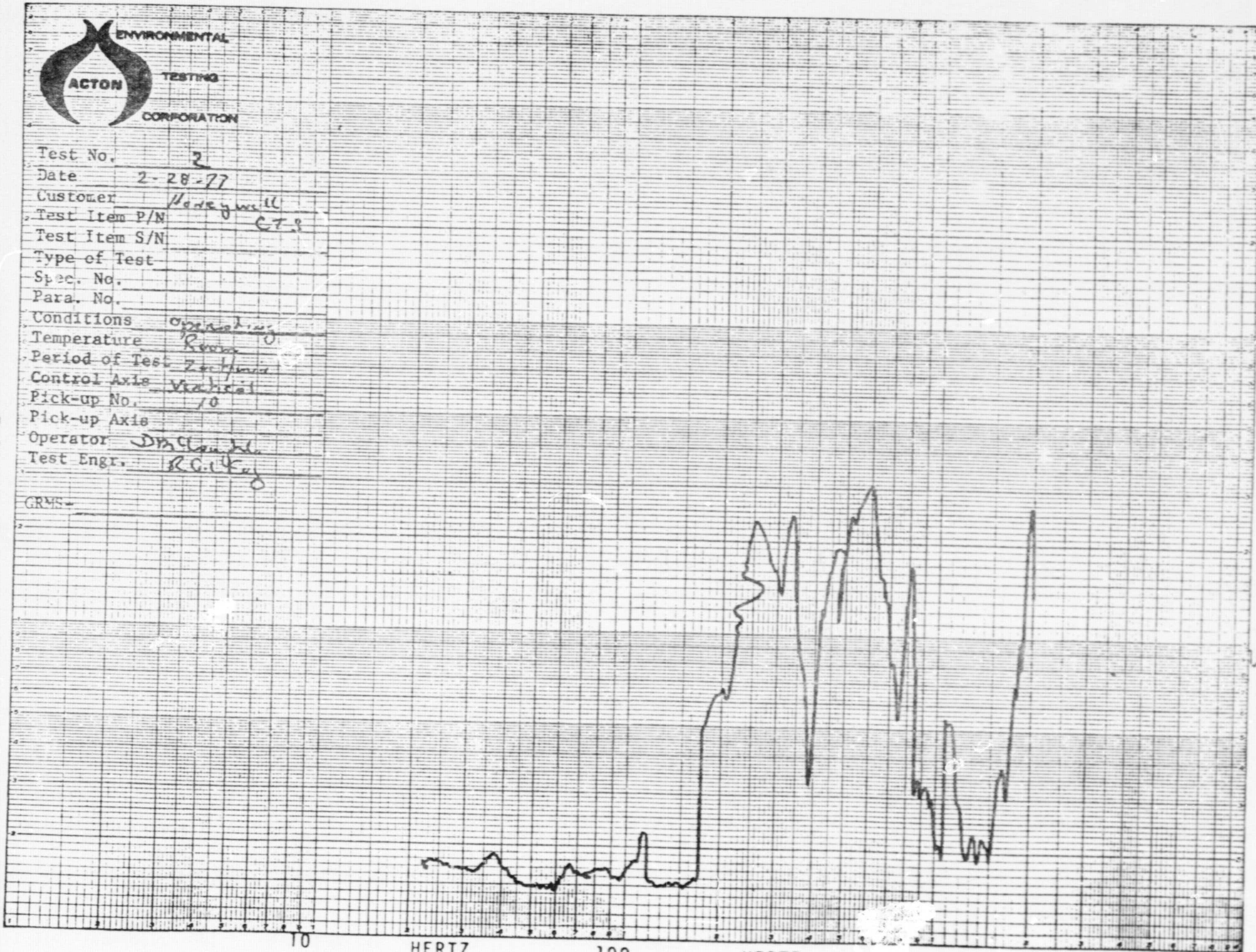

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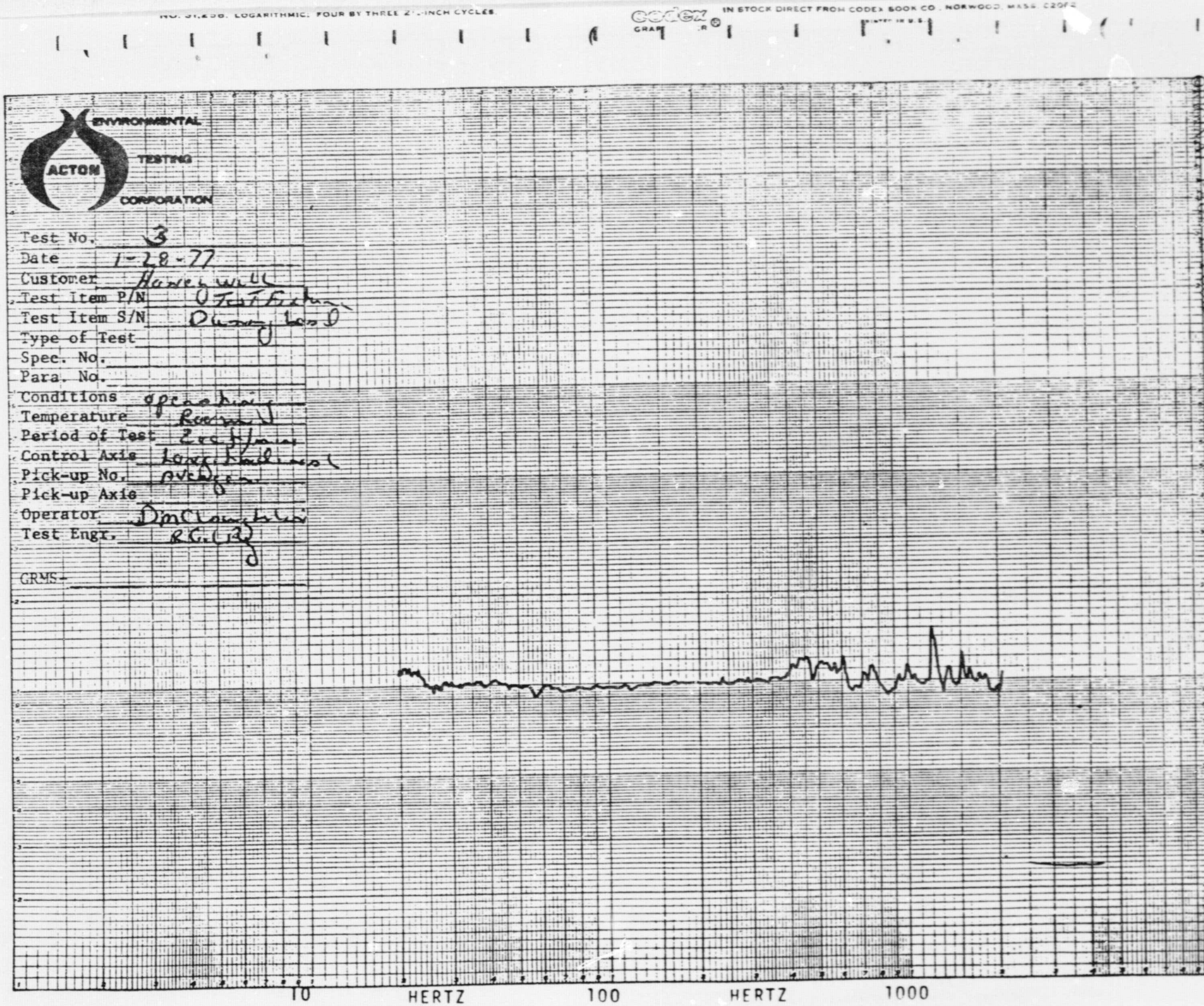

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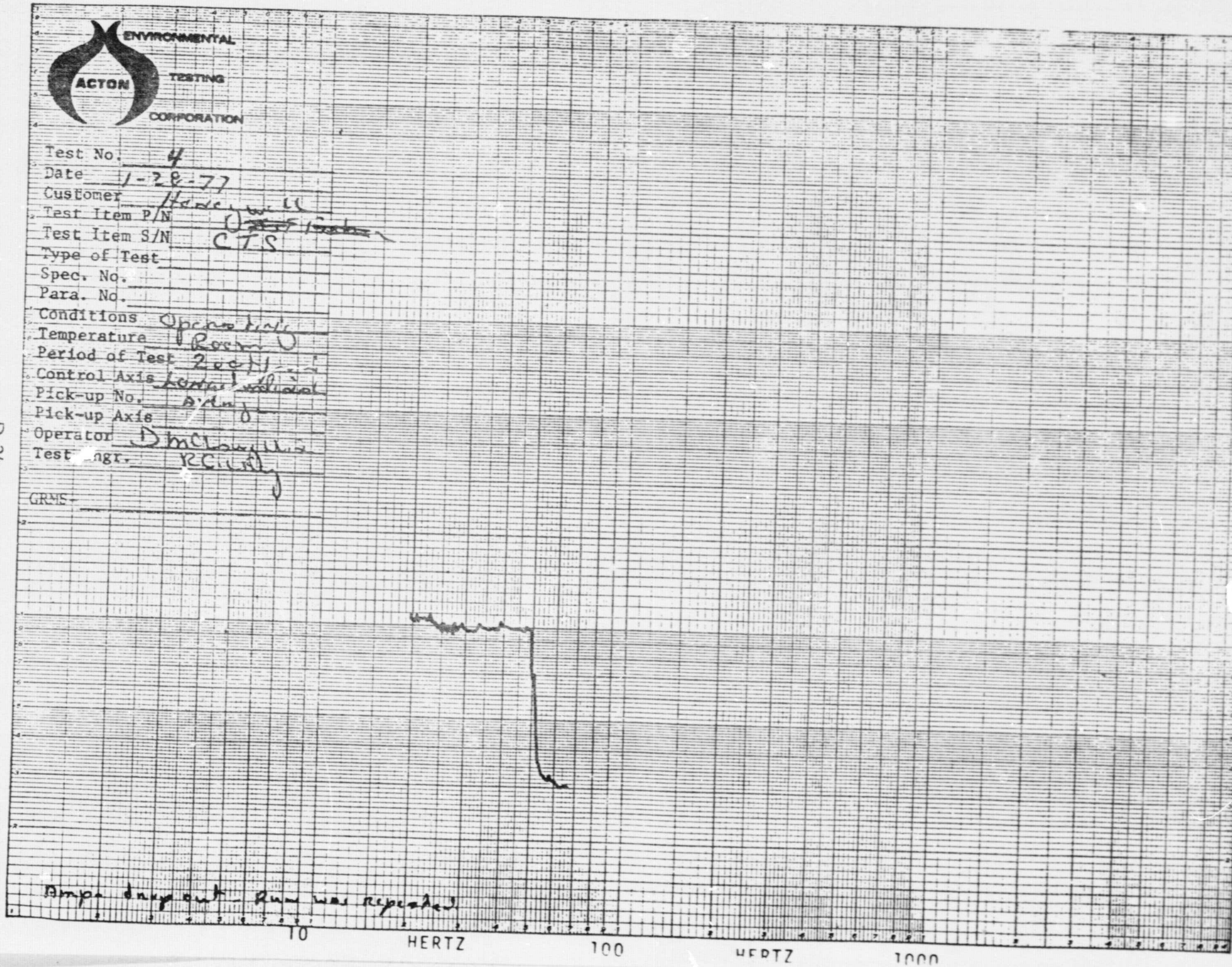

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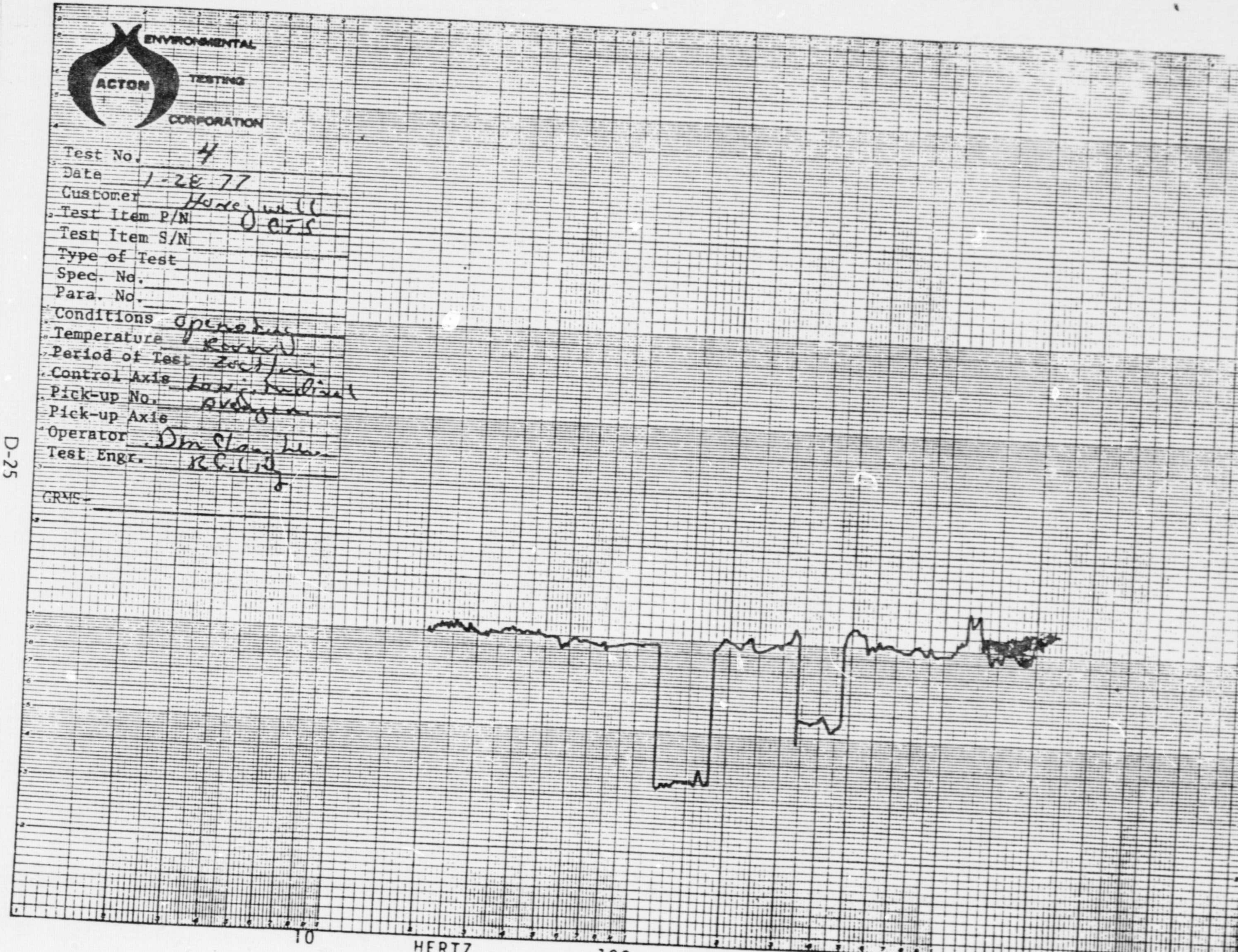
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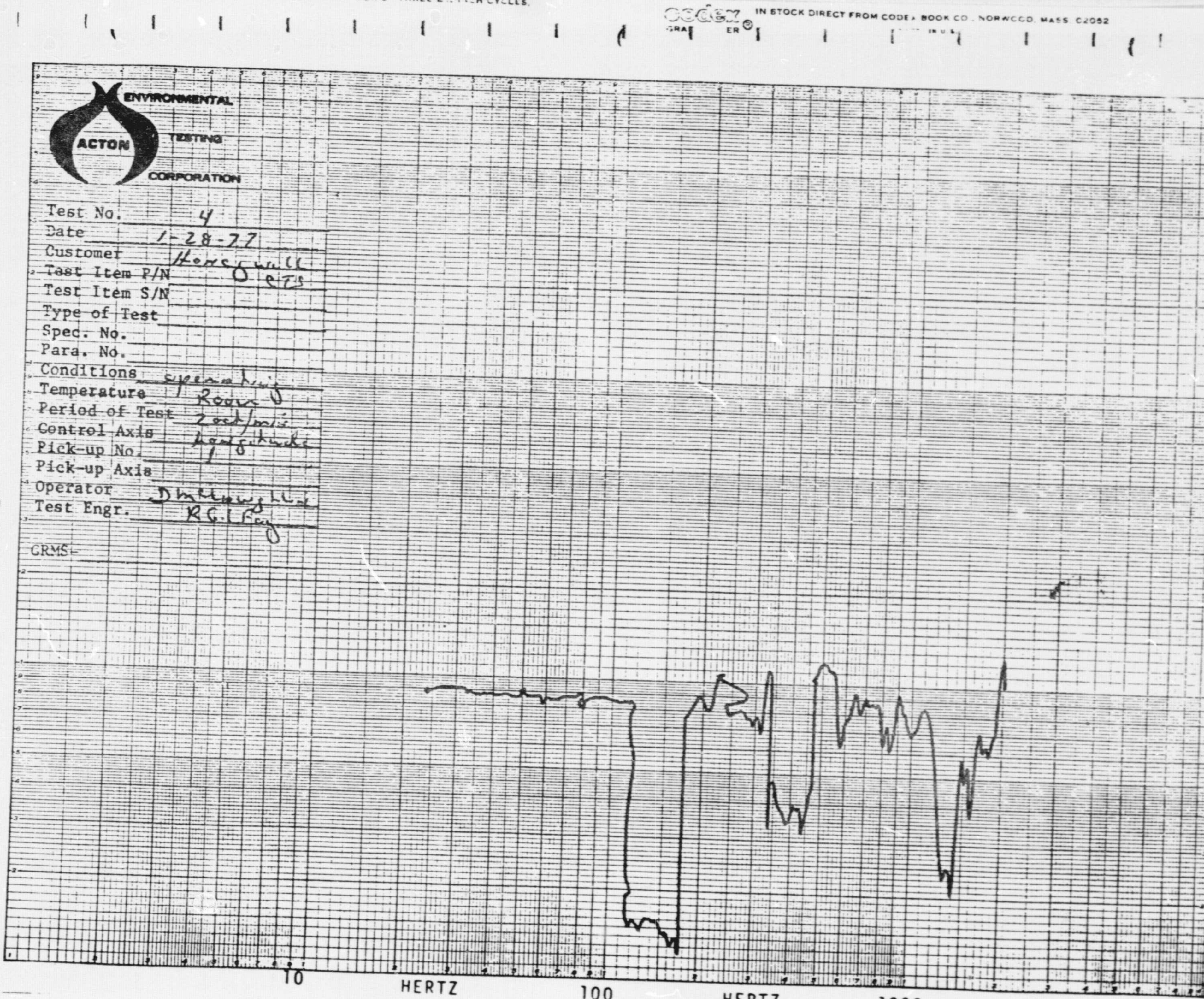
Test No. 4
Date 1-28-77
Customer Honeywell
Test Item P/N
Test Item S/N
Type of Test
Spec. No.
Para. No.
Conditions Operating
Temperature Room
Period of Test
Control Axis
Pick-up No.
Pick-up Axis
Operator
Test Engr.
GRMS -
10
HERTZ
100
HERTZ
1000
10
.5
10

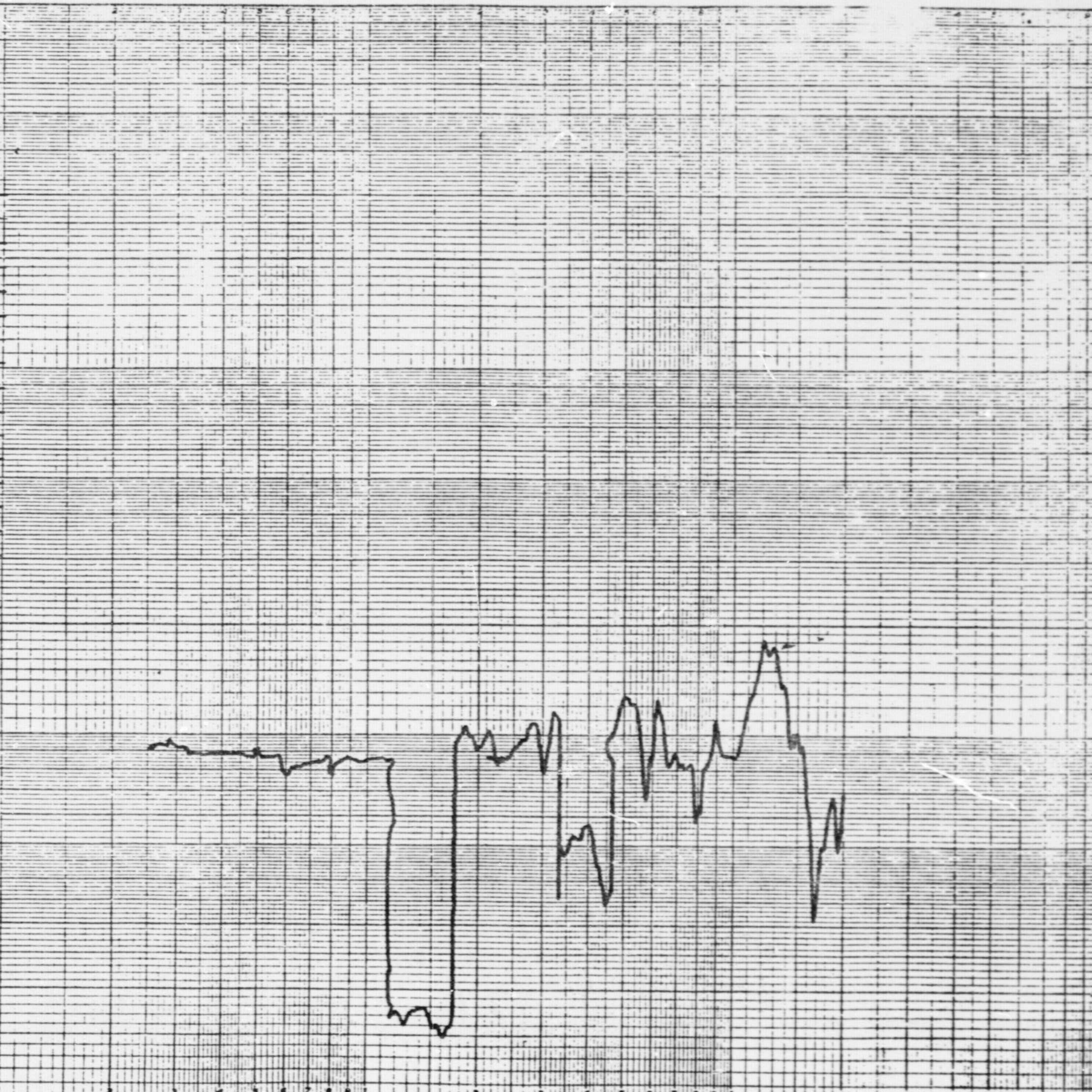

IN STOCK DIRECT FROM CODEX BOOK CO. NORWOOD, MASS. 02062
ENVIRONMENTAL
ACTON
TESTING
CORPORATION
Test No. 4
Date 1-28-77
Customer Honeywell
Test Item P/N
Test Item S/N
Type of Test
Spec. No.
Para. No.
Conditions operating
Temperature Room
Period of Test 2 oct/min
Control Axis Longitudinal
Pick-up No. 1
Pick-up Axis
Operator D McLaughlin
Test Engr.
GRMS-
1.0
10
HERTZ
100
HERTZ
1000

24

ACTON ENVIRONMENTAL TESTING CORPORATION

Test No. 4
Date 1-28-77
Customer Honeywell
Test Item P/N CTS
Test Item S/N
Type of Test
Spec. No.
Para. No.
Conditions operating
Temperature Room
Period of Test 2oct/min
Control Axis Longitude
Pick-up No. 2
Pick-up Axis
Operator D McLaughlin
Test Engr. R. C. Clay

GRMS=



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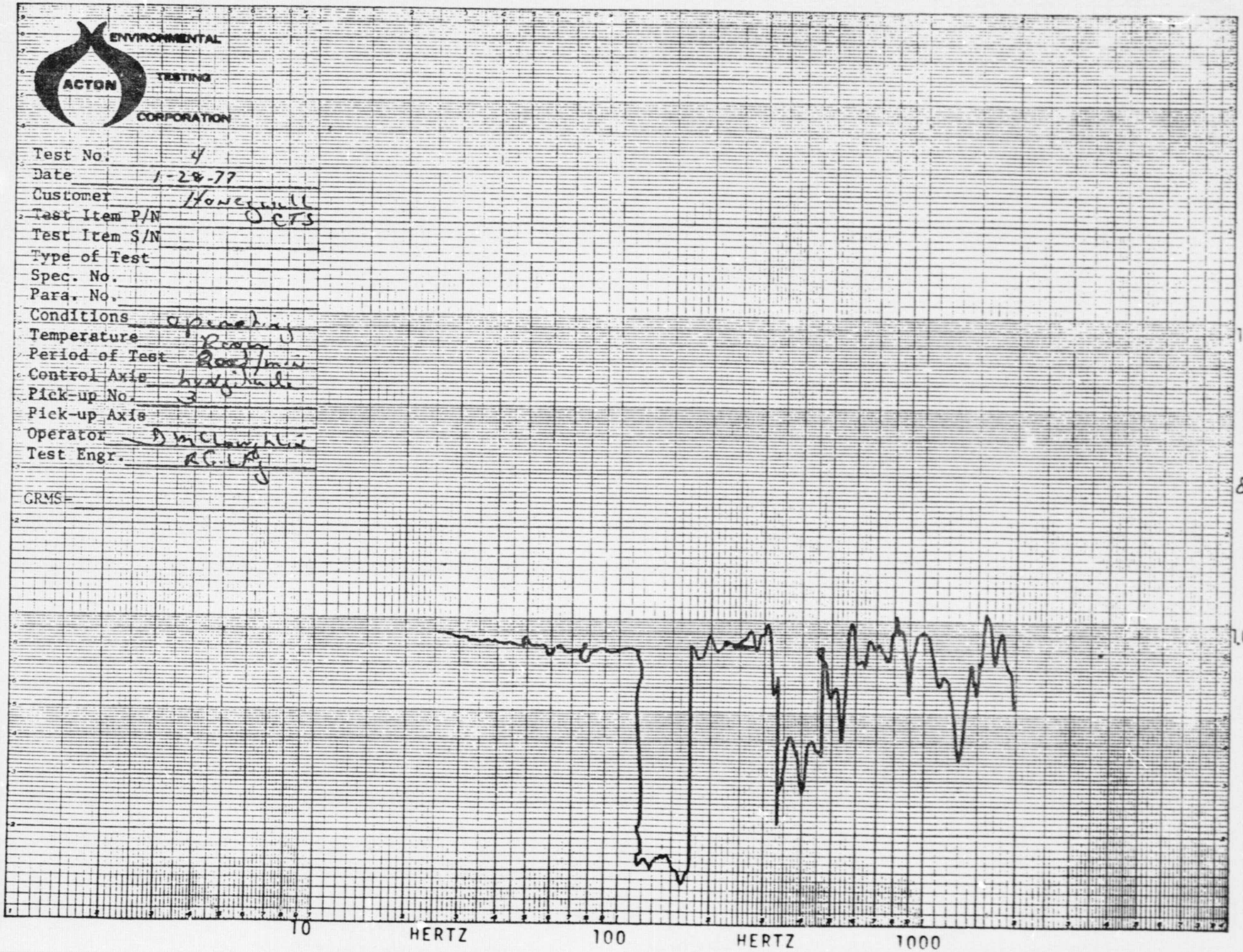
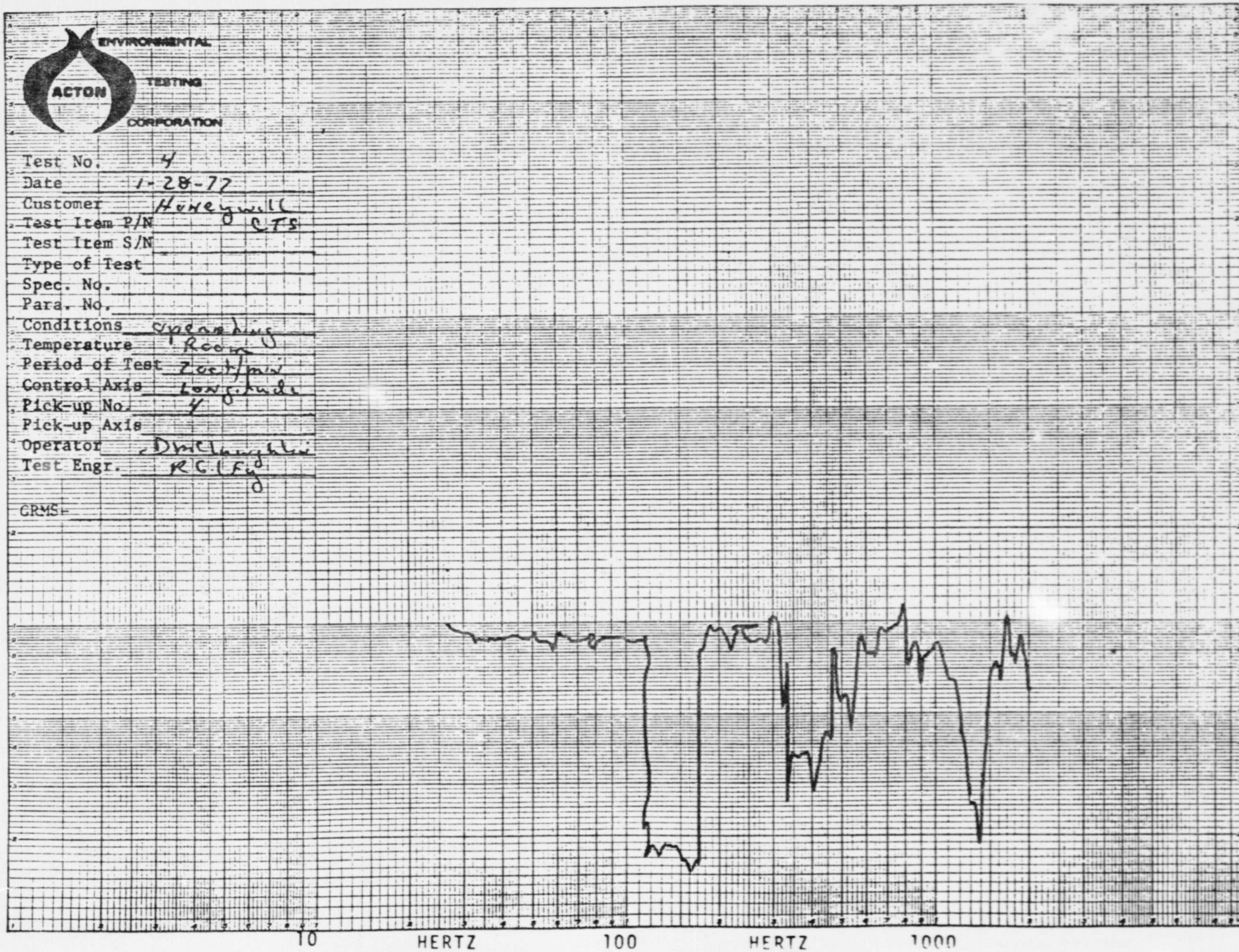

ENVIRONMENTAL
ACTON
TESTING
CORPORATION
Test No. 4
Date 1-28-77
Customer Honeywell
Test Item P/N OCTS
Test Item S/N
Type of Test
Spec. No.
Para. No.
Conditions operating
Temperature Room
Period of Test Rand/min
Control Axis Longitudinal
Pick-up No. 3
Pick-up Axis
Operator D McLaughlin
Test Engr. RCLA
GRMS=
10.
.85
1.0
10
HERTZ
100
HERTZ
1000

26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Test No. 4
Date 1-28-72
Customer Honeywell
Test Item P/N CTS
Test Item S/N
Type of Test
Spec. No.
Para. No.
Conditions operating
Temperature Room
Period of Test 2oct/min
Control Axis Longitude
Pick-up No. 4
Pick-up Axis
Operator D McLaughlin
Test Engr. RC Lg
GRMS=
10
8
1.0
10
HERTZ
100
HERTZ
1000

NO. 31.258. LOGARITHMIC: FOUR BY THREE 2½-INCH CYCLES.

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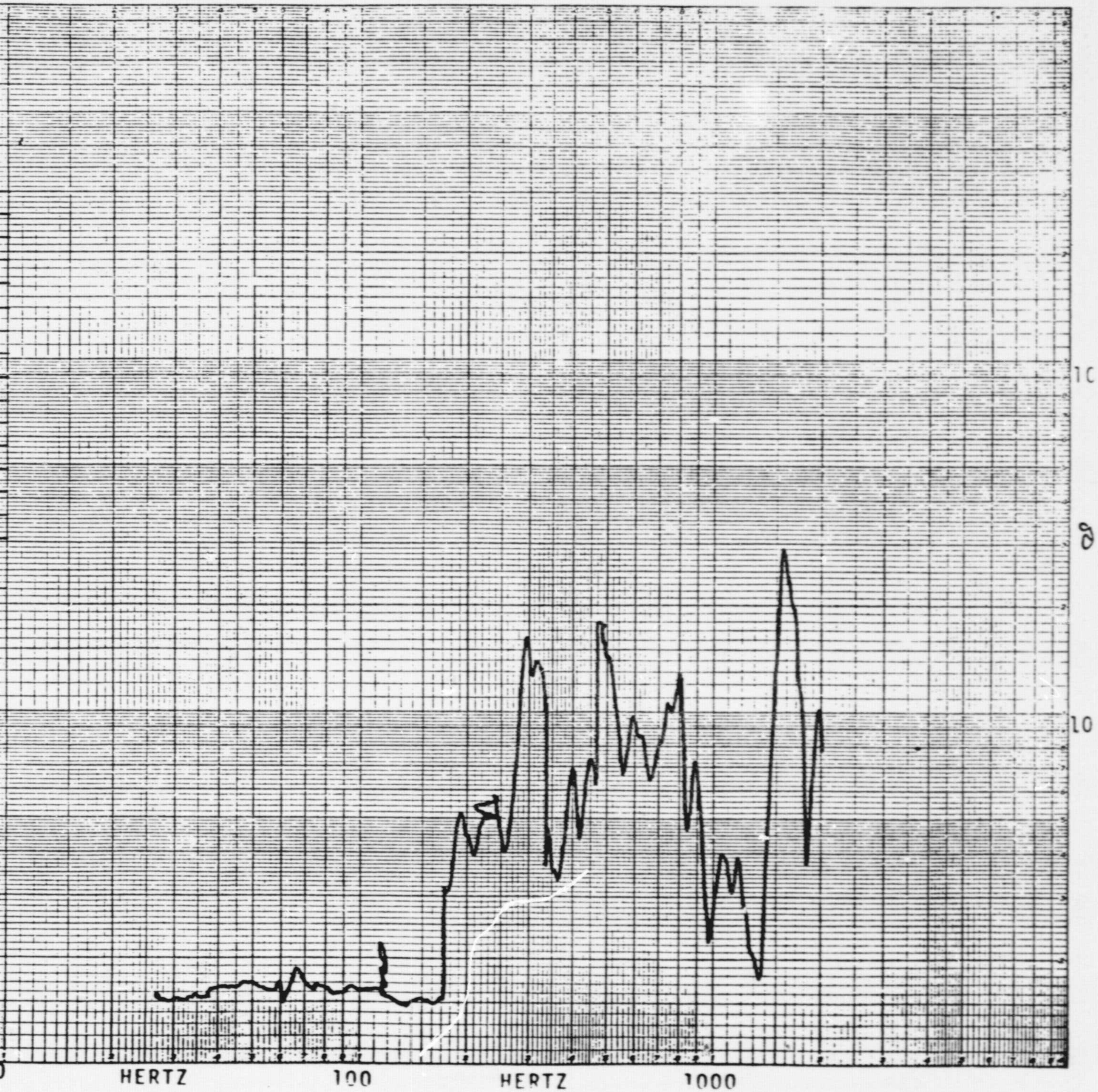
ACTON ENVIRONMENTAL TESTING CORPORATION

Test No. 4
Date 1-28-77
Customer Honeywell
Test Item P/N CTS
Test Item S/N
Type of Test
Spec. No.
Para. No.
Conditions Operating
Temperature Room
Period of Test Zero/min
Control Axis Longitude
Pick-up No. 3
Pick-up Axis
Operator D McLaughlin
Test Engr. R.G. Ley

GRMS=



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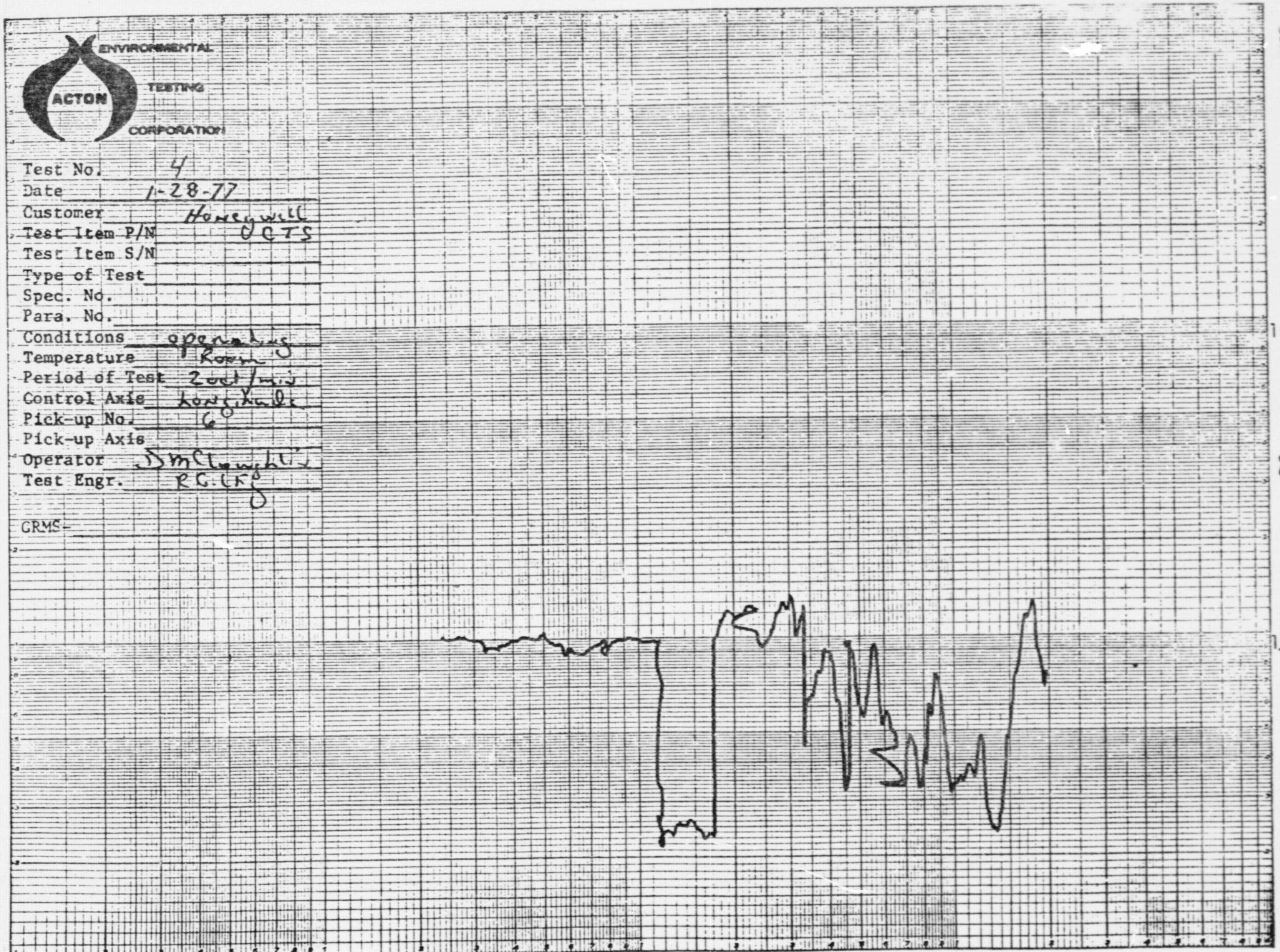
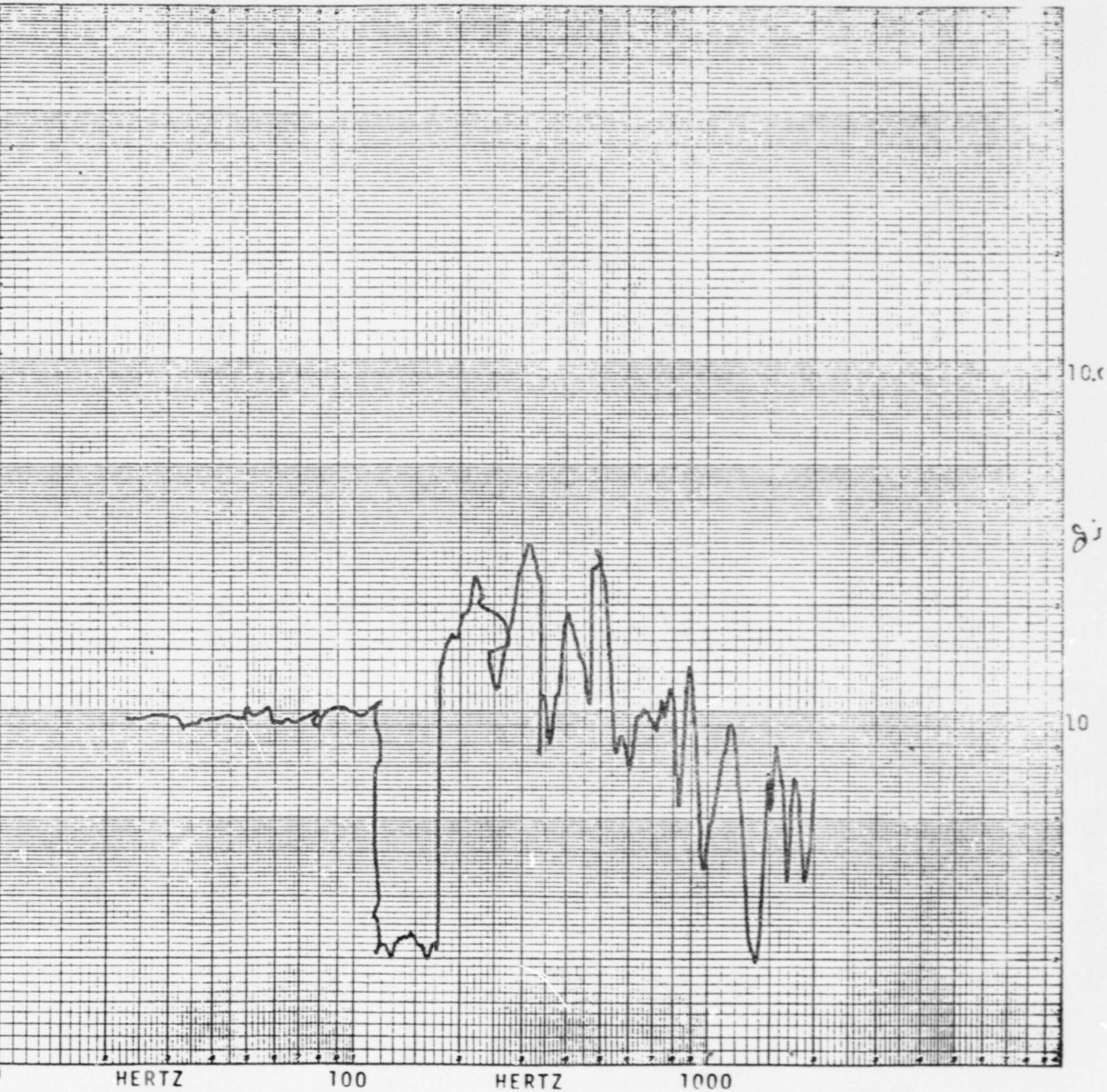


ACTON ENVIRONMENTAL TESTING CORPORATION

Test No. 4
Date 1-28-77
Customer Honeywell
Test Item P/N CTS
Test Item S/N
Type of Test
Spec. No.
Para. No.
Conditions operating
Temperature Room
Period of Test 4 oct/min
Control Axis Longitude
Pick-up No. 7
Pick-up Axis
Operator D McLaughlin
Test Engr. RCLFay

GRMS-



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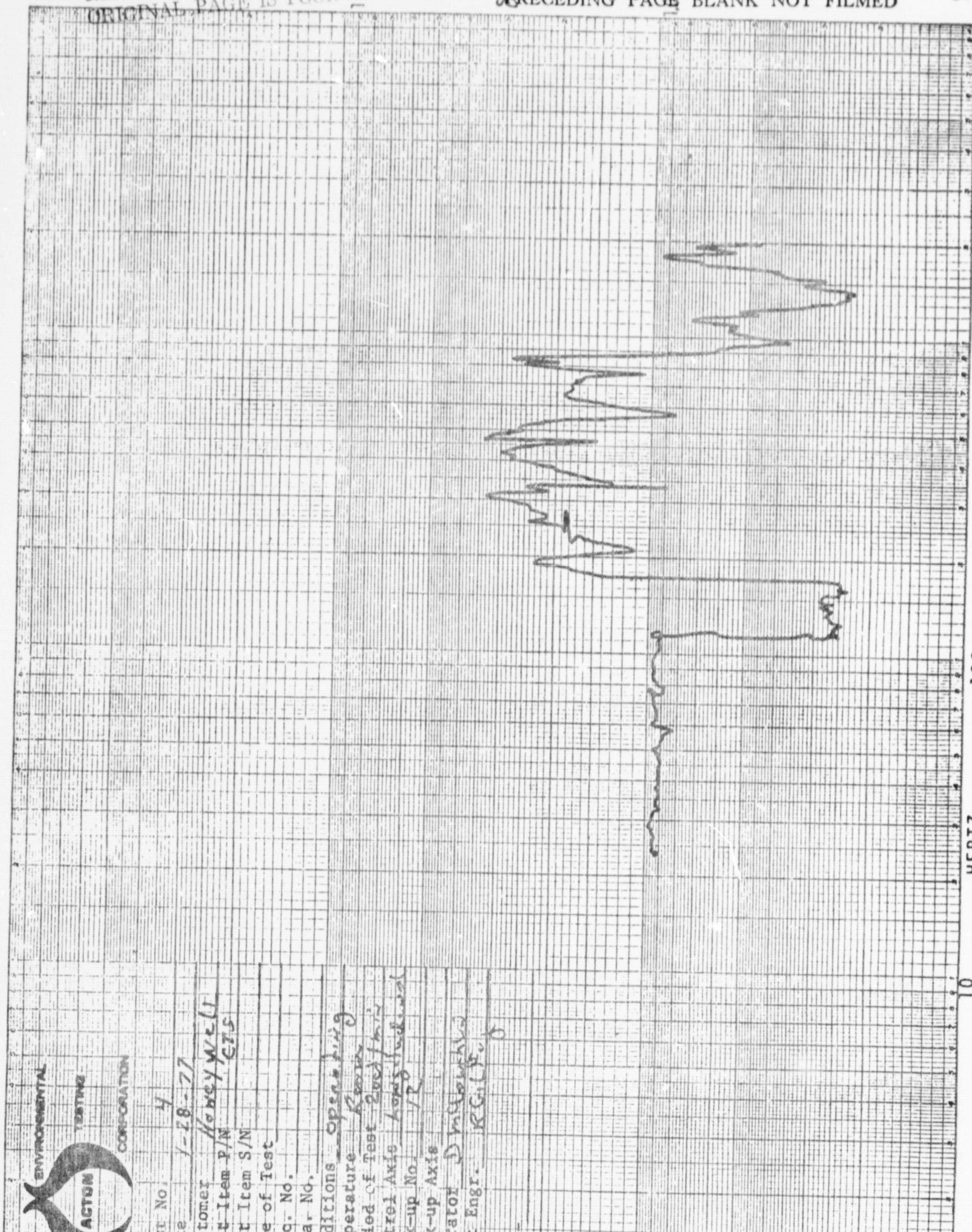
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ACTON
Test No. 4
Date 1-28-77
Customer Honeywell
Test Item P/N
Test Item S/N
Type of Test
Spec. No.
Para. No.
Conditions Operating
Temperature Room
Period of Test
Control Axis
Pick-up No.
Pick-up Axis
Operator
Test Engr.
GRMS
10
100
1000
HERTZ
HERTZ